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TEST OF SEEDS OF MOHAVE DESERT SHRUBS

PROGRESS REPORT

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Foreword

The following studies resulted from interest expressed by Mr. Carl Rice and others of the Bureau of Land Management. The study represents work of myself as project leader; Dr. W. A. Williams, Professor of Agronomy; Mr. Richard E. Owen, my assistant; and students Walter Graves (now Farm Advisor, U.C. Cooperation Extension, San Diego Co.), Duane Cornett, Doug Miles, and Catherine M. Ross). Also, closely related studies with Dr. James A. Young and Dr. Raymond A. Evans of Agricultural Research Service, USDA, Reno, Nevada and have contributed to various aspects of the studies reported here.

In addition to the original interest in revegetation of the aqueduct scar, there is interest from other agencies in using these same species on road-sides in the California desert.

This progress is the third presented in the course of this contract. The first was dated FY 1974.

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COMPLETED STUDIES

"Seed-Treatment of Mojave Desert Shrubs" by Walter L. Graves, Burgess L. Kay, and William A. Williams was published in the Agronomy Journal Vol. 67, Nov.-Dec. 1975 pp. 773-777. This includes studies of the original seven species and is reprinted here in Appendix I.

"Revegetation of disturbed sites with native shrub species in the western Mojave Desert", by Walter L. Graves, has been completed, and the manuscript appears in Appendix II. This reports on the results of field studies at two Mojave Desert sites in both direct seeding and transplanting of seven shrub species. Additional financial support was provided by a University of California Chancellor's Patent Fund Research Grant.

A complete description of "Collection, processing, analysis and storage of seeds of Western Mojave Desert shrub species" appears in Appendix I of FY 1975. This describes in detail the preparation of seed to be used in the long-term seed storage experiment and briefly lists the results of the first years' storage.

Depth-of-planting studies with the expanded list of species appear in FY 1975 Appendix II as "Mojave Desert Shrub depth-of-planting study, 1973-74." Principal criteria of evaluation where time from planting to emergence, and total number of seedlings emerged from planting depths of 1, 2, and 4 cm.

The effects of various constant temperatures from 0 to 40 C on germination of desert shrubs have been compiled, largely through the efforts of Dr. James Young. These appear as FY 1975 Appendix III. This information will be used to alter the germination conditions to be used in the long-term seed storage experiment.

"Germination of Native Desert Shrubs", by W. A. Williams, O. D. Cook, and B. L. Kay was also published in August 1974 in California Agriculture Vol. 28, No. 8, p. 13, and reprinted in FY 1975 progress report Appendix IV.

A paper titled "Ephedra germination", by James A. Young, Raymond A. Evans, and Burgess L. Kay, has been submitted to a Journal. This study compares green ephedra (E. viridis) and Nevada ephedra (E. nevadensis). Their germination in relation to constant and alternating temperatures and osmotic potentials was investigated. Both species germinated over a relatively large range of temperatures. Nevada ephedra was optimum in germination at constant temperatures except for the 20/25 C regime. Green ephedra had optimum germination at combinations of cold night temperatures (2 or 5 C) and moderate day temperatures (15 to 25 C). Low osmotic potentials reduced germination more in the green than the Nevada seeds.

MOJAVE REVEGETATION NOTES

A series of short papers on both seed and seeding data and general information and literature review are planned. These will include photographs of the seed, seedling, and mature shrub. A first draft of two of these are included as Ambrosia dumosa (Appendix III) and Larrea tridentata (Appendix IV). Ms. Catherine M. Ross was primarily responsible for preparation of the photographs and manuscripts.

MISCELLANEOUS

Seed of eight shrubs (total 47.5 lbs) was supplied to Mr. Stewart Porter of BLM for revegetation of motorcycle-damaged areas in April 1975. A similar request by Dick Harlow and Louis A. Boll of the BLM Bakersfield office was honored for about 2.5 lb in April 1976. This has exhausted the extra seed collected in the initial phases of this study.

SEED STORAGE

A long-term seed storage experiment was started in December 1973. Seeds were packaged in lots large enough for at least 500 viable seeds, dried to less than 7% moisture (varying from 1.5 to 9.4% for different species) and then stored under one of four storage treatments. Treatment one was stored in bags in the Crop Improvement Association warehouse as a "Typical warehouse condition." These seeds will be subjected to the normal fluctuation of temperature and moisture. The remaining 3 treatments consist of 21 individual packets of dry seed sealed in one-gallon glass jars. Twenty such jars are stored at each room temperature, cold storage (4C), and frozen (-15C). One jar of each will be opened annually for a germination test to compare with the warehouse samples.

The date of testing was shifted from January to June to complement the schedule of the Foundation Seed Program. We are fortunate to receive the assistance of their registered seed analyst in making the germinations and to utilize their controlled-temperature facilities to benefit from the information recently obtained on the effect of temperature. This should add continuity to the long-term study. These seeds were germinated in January 1975 by Duane Cornett, a graduate student, and again in June 1975, by Martha Chan, a registered seed analyst. Both sets of data appear in Table 1. There were some differences in results that could not be explained by the elapsed time. The temperatures used were altered with some species to conform to the optimum temperatures reported last year. Other differences may be selectivity on the choice of seeds by the graduate student. Hopefully the use of a registered seed analyst will reduce this error.

The results are presented only as a progress report, and further analysis when more data is available may change the overall picture. Following are preliminary observations:

Table 1. Effect of seed storage conditions on % germination--4-week germination time*.

Storage conditions	Dec. 73	Jan. 75				May 75			
	Warehouse	-15C	4C	Room temp	Warehouse	-15C	4C	Room temp	Warehouse
Acamotopappus sphaerocephalus	11	5	6	4	2	3	3	2	2
Ambrosia dumosa	5	7	7	5	8	7	6	10	6
Ambrosia dumosa - 1974 col.		7	12	18	12	6	6	8	9
Atriplex canescens 3,000′	3	8	10	9	6	5c	7bc	10b	18a
Atriplex canescens 4,000′	23	35a	38a	40a	19b	36	42	32	36
Atriplex polycarpa	23	26	30	26	23	21	27	28	30
Cassia armata	75	35b	26c	41b	85a	33bc	29c	40b	82a
Ceratoides (Eurotia) lanata	22	17a	21a	18a	0b	28a	31a	22a	0b
Chrysothamnus nauseosus var hololeucus	22	22	20	30	26	18a	26a	21a	10b
Encelia virginensis	77	80a	71b	78a	72b	14	12	15	20
Ephedra nevadensis	68	36	26	32	25	16	16	15	14
Ephedra viridis	38	35b	35b	42b	65a	82a	84a	84a	66b
Eriogonum fasciculatum	4	6b	15a	5b	10ab	34a	14b	25ab	5c
Grayia spinosa	42	44ab	48ab	55a	38b	50	52	50	50
Hymenoclea salsola	68	65	66	66	69	56	58	53	68
Isomeris arborea	38	69	68	69	76	78ab	81a	85a	65b
Larrea tridentata	6	6bc	8b	5c	12a	2	4	3	4
Lepidium fremonti	0	1	0	1	1	1	0	0	1
Lepidospartum squamatum	58	23b	19b	28b	47a	21a	16a	12a	3b
Lycium andersonii	9	4b	8a	10a	10a	6	6	8	7
Lycium cooperi	19	26	31	27	24	13	18	18	20
Prunus andersonii		0	1	2	1	7	3	0	7
Salazaria mexicana	84	83b	94a	91a	92a	44a	44a	43a	33b
Yucca brevifolia var herbertii		94	93	92	90	44ab	46a	45a	42b

* Values followed by the same letter are not significantly d'fferent at the 5% level. Significance based on the arcsine transformation and Fishers LSD test.

Acamptopappus sphaerocephalus germination was very poor, and not improved by any storage treatment. Germination was best in the second week.

Ambrosia dumosa germination was poor and not improved by any storage treatment. The 1974 collection does not appear to be better than the 1973. Germination was best in the second week.

Atriplex canescens 3,000′ showed reduced germination by all treatments in May 1975. The -15C reduced germination further. There was no similar trend for the sample collected at 4,000′. The reduction in the 3,000′ sample is probably due to the excessive drying of the sample of 1.5% moisture (compared with 3.4% in the 4,000′ sample). Germination was best in the second week (3,000′) and first and second weeks (4,000′).

Atriplex polycarpa showed no difference due to treatment. Germination was best in the first week.

Cassia armata germination was reduced to one-half or less by all storage treatments. Germination was best in the first and second weeks.

Ceratoides lanata (formerly Eurotia lanata) germination was reduced to zero by the sack storage and maintained at 22-28% by all storage treatments, with no difference between treatments. Germination was best in the first week.

Chrysothamnus nauseosus var. hololeucus was about doubled by all storage treatments, with no difference between treatments. Germination was best in the first week.

Encelia virginensis germination was not affected by treatment in the May test. The higher germination in January may have been due to the selection of the "best" seeds. Germination was best in the first and second week.

Ephedra nevadensis was not affected by treatment. However, the germination in May was one-half that of the January germination. The May test was at 15C, which should be better than the 20C used in January. Germination was best in the first week.

Ephedra viridis was improved by all storage treatments in the May test and reduced by all treatments in the January test, though the sack storage results were identical. This is apparently due to the use of alternating temperatures of 5-15C in May, compared with a constant 20C in January. Germination was best in the second and third weeks.

Eriogonum fasciculatum germination seemed to be improved by all storage treatments. May results were much improved over January, possibly because of the change from 20C to 15C. Germination was best in the first week.

Grayia spinosa germination was not effected by any treatment in May. Germination was best in the first week.

Hymenoclea salsola germination was not improved by any treatment. Germination was best in the second week.

Isomeris arborea germination was improved by all treatments. Germination was best in the first and second weeks.

Larrea tridentata and Lepidium fremontii germination was poor in all conditions. Germination was best in the first week.

Lepidospartum squamatum germination was much better in all storage treatments in the May test, but reduced by all treatments in January. Temperatures were reduced from 20C to 5C. This may represent an actual decline in germination in sack storage. Germination was best in the first week.

Lycium andersonii was poor in all treatments. Germination was best in the second and third weeks.

Lycium cooperi was not affected by treatment. Germination was best in the second and third weeks.

Prunus andersonii was poor in all treatments. Germination was best in the third and fourth weeks.

Salazaria mexicana germination was improved by all treatments in the May test 15C, but values were less than one-half those in January 20 C.

Yucca brevifolia var. herbertii germination was only slightly improved by the room temperature and 4C treatments, but not by the -15C. Results in May were only 50% of those in January. Germination was best in the first week.

Seed Treatment of Mojave Desert Shrubs[1]

Walter L. Graves, Burgess L. Kay, and William A. Williams[2]

ABSTRACT

Information is needed for revegetation of barren scars left from destruction of native shrubs by recreational vehicles and right-of-way clearance. Numerous seed treatments were tested for improvement of field establishment of Mojave Desert shrubs and reduction of establishment costs.

Scarification, 4-hour 60 C and 80 C dry heat, stratification, activated carbon, 3-hour and 15-hour soaking, 100 ppm and 1,000 ppm ethylene, hot water (5 min), 0.5 and 6% sodium hypochlorite, 3% thiourea, and 6% hydrogen peroxide were used on the following species considered promising for revegetation: 1) *Larrea divaricata* Cav., 2) *Atriplex polycarpa* (Torr.) Wats., 3) *Atriplex canescens* (Pursh.) Nutt., 4) *Hymenoclea salsola* T. & C., 5) *Ephedra nevadensis* Wats., 6) *Ambrosia dumosa* (Gray) Payne *Franseria dumosa*), and 7) *Lepidospartum squamatum* Gray.

Activated carbon was the most effective treatment in improving fruit germination on 5 of 6 species tested (spp. 1, 2, 4, 5, 6). Stratification was effective on improving the germination of 3 of 6 species (spp. 2, 3, 6). Thiourea (3%) was effective in improving the germination of both the carpels and seeds of *Larrea divaricata*. The 15-hour soaking, 100 ppm ethylene, 4-hour 60 C, and scarification treatments improved the germination of only one species each. Treatments having no effect on germination were 3-hour soaking, 6% hydrogen peroxide, and 1,000 ppm ethylene. The 4-hour 80 C dry heat depressed the germination of 5 of the 7 species and 6% sodium hypochlorite depressed the germination on all species tested. Hot water (5 min) killed the embryos on all species tested.

Additional index words: Larrea divaricata, Atriplex polycarpa, Atriplex canescens, Hymenoclea salsola, Ephedra nevadensis, Ambrosia dumosa (syn. *Franseria dumosa*), *Lepidospartum squamatum*, Activated carbon, Thiourea, Hydrogen peroxide, Sodium hypochlorite, Ethylene.

MAN'S increased activities in the deserts of California have interfered with the delicate balance between desert plant life and the environment. Some uses eliminate the protective cover of native perennial vegetation. Examples are offroad vehicles and the Los Angeles Aqueduct, stretching across the entire west side of the Mojave Desert, where construction has left a barren strip several hundred kilometers long. The Bureau of Land Management, which is interested in revegetating public land, obtained seeds of seven common Mojave Desert species: *Larrea divaricata* Cav. (creosote bush), *Atriplex polycarpa* (Torr.) Wats. (desert saltbush), *Atriplex canescens* (Pursh.) Nutt. (fourwing saltbush), *Hymenoclea salsola* T. & C. (white cheesebush), *Ephedra nevadensis* Wats. (Nevada ephedra), *Ambrosia dumosa* (Gray) Payne [*Franseria dumosa*] (white bursage), and *Lepidospartum squamatum* Gray (scalebroom). Williams et al. (1971) completed an initial study of the characteristics, germination, and depth of emergence of these seeds. *Larrea divaricata, Atriplex polycarpa,* and *A. canescens* were shown to have a low and slow seed germination and seed coats which make reseeding difficult by conventional methods. Earlier studies of germination and seed treatment have been made on three of the seven species considered here.

Barbour (1968), working with *Larrea divaricata* seeds from sites in the three desert regions of the southwestern U.S. (Chihuahuan, Sonoran, and Mojave), found that pericarp removal had no effect on germination. A 30-day 0 C treatment improved the germination of seed from the Sonora and Chihuahuan Deserts but decreased the germination of seed from the Mojave Desert. A heat treatment of 71 C for 7 days reduced germination. Knipe and Herbel (1966) observed that extracts from *Larrea divaricata* carpels did not affect the total germination of seeds removed from the carpels although such seeds germinated faster.

As for *Atriplex polycarpa,* Cornelius and Hylton (1969) found that leaching enhanced germination whereas the leachate from the seeds suppressed germination, indicating an inhibiting substance. Chatterton (1970) found that 60 and 70 C for 4 hours improved the germination of 1-year-old seed of *A. polycarpa* collected from different California sites. In addition, both light and leachate reduced germination.

Atriplex canescens has been studied the most extensively. Twitchell (1955) reported that germination of *A. canescens* was improved by soaking in water for several hours and drying for 7 days. Nord and Van Atta (1957) reported that heavy scarification increased germination. An inhibitor in the bracts of *A. canescens* was suspected of suppressing germination, and Nord and Van Atta (1960) showed that saponin from the bracts of this species inhibited germination. Springfield (1970) used various treatments on seeds from Arizona, New Mexico, and Utah. Dewinging with a hammermill hastened germination but did not increase 28-day germination. Scarification effects varied with seed source, amount of scarification, and seed-coat characteristics (thin-coated seeds were harmed by very light scarification whereas thick-coated seeds benefited).

Improvements in processing and seed germination would aid seedling establishment and reduce costs. This study considered the effects of various seed treatments and seed-coat modifications on the germination of *Larrea divaricata, Atriplex polycarpa, A. canescens,* and, to a lesser extent, the other four species.

MATERIALS AND METHODS

The seeds were collected by a commercial seed collector from December 1970 to October 1971 on the west side of the Mojave Desert at approximately 900 m (3,000 ft) elevation. Samples were

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obtained in March 1972 and placed in cold storage (10 C). Germination obtained by Williams et al. (1974) indicated that only *Larrea divaricata*, *Atriplex polycarpa*, and *A. canescens* seeds had poor 7-day germination (respectively 10, 4, and 21% of that of potentially viable seeds).

Larrea divaricata fruits were processed on a belt thresher used to hull alfalfa seeds, and the seeds were separated on a Clipper cleaner. The fruit coat of *Atriplex polycarpa* (thought to inhibit germination) was completely removed by scarification of 800-fruit samples for 1 min at 2.1 kg/cm² (30 psi) on a coarse grade of emery cloth in a 5.6 × 7.5-cm (2.25 × 3 in) cylinder, sieving on a 1.6-mm (4/64 in) round-hole screen to remove the smaller scarified seeds, and continuing scarification on larger seeds for 1 additional minute. *A. canescens* was dewinged similarly on a 19-mm (48/64 in) screen.

Heat treatments of 60 and 80 C were applied to all seven species. Seeds or fruits were spread on metal platters and subjected for 4 hours to forced-air heat. All treatments were made on 400 seeds or fruits of all species (unless otherwise noted), except for *A. canescens*, where 200 fruits were used.

Stratification in moist sand at 2 C for 30 days was performed on all species except *Larrea divaricata* hulled seeds and *Lepidospartum squamatum*. *A. canescens* fruits received only a 15-day stratification.

In the activated carbon treatment, seeds or fruits were mixed with 100 g moistened 12 × 50-caliber activated carbon in plastic bags loosely sealed at the top, allowing room for air expansion, and stored for 30 days at 2 C. Seeds were allowed to dry for 2 days before testing.

Soaking treatments used on *Larrea divaricata* (hulled and unhulled), *A. polycarpa*, and *A. canescens* fruits consisted of a 3-hour soaking in tap water at 20 C, or a 15-hour soaking with the water changed every 3 hours followed by air drying for 2 days at 25 C.

Two ethylene treatments were given *Larrea divaricata* (hulled and unhulled) and *A. polycarpa* seeds, and one ethylene treatment was given *A. canescens* fruits. Fruits or seeds were moistened and placed in quart jars with 100 or 1,000 ppm of ethylene for 24 hours at room temperature, after which the seeds were air-dried at 25 C for 3 days. Since radicle protrusion had begun during the 24-hour treatment of the hulled *Larrea divaricata*, they were germinated immediately.

A boiling-water treatment was given fruits of *Larrea divaricata*, *A. polycarpa*, and *A. canescens*. Tap water was brought to a boil, the heat turned off, and the fruits placed in the near-100 C water for 5 min and then air-dried for 3 days.

Treatments with 0.5 and 6% sodium hypochlorite (24 hours), 3% thiourea, (5 min), and 6% hydrogen peroxide solutions were made on *Larrea divaricata* (hulled and unhulled) seeds, and on fruits of *A. polycarpa* and *A. canescens*. The hydrogen peroxide treatment time was 10 min for *Larrea divaricata* carpels and *A. polycarpa* fruits, 5 min for *Larrea divaricata* seeds, and 20 min for *A. canescens* fruits. Rinsing was for 2 min followed by air-drying for 3 days. Table 1 summarizes the treatments.

The fruits or seeds from all the above treatments were germinated on inclined germination plates of paper with plexiglass backing. The seeds of each species were divided into four 100-seed lots (four 50-fruit lots for the *A. canescens*), placed on each germinating plate in 10 rows, covered with tissue paper, wetted to maintain the seed on the blotter paper, and arranged upright in a randomized manner on racks wicked in glass dishes filled with distilled water. The germination dishes were then placed in a dark chamber for 48 hours at 12 C, followed by 12 days at 21 C. *Larrea divaricata* was placed in a 26 C dark chamber for an additional 7 days (Barbour 1968). The plates were counted daily for the first 10 days, and thereafter every two days, except for *Larrea divaricata*, which was counted daily through the first 18 days. Seeds were considered germinated and removed from the plates when normal radicles had developed to a length of 10 mm. Analysis of variance was performed by arcsine transformation on the 7 and 14-day results and, where applicable, the 21-day results. When the F-test indicated significant differences among treatments ($P < 0.05$), Duncan's new multiple-range test was used (Duncan, 1955).

RESULTS AND DISCUSSION

Figure 1 illustrates the germination of *Larrea divaricata* unhulled and hulled seeds; *Atriplex polycarpa*, *A. canescens*, and *Hymenoclea salsola* fruits; *Ephedra nevadensis* seeds; *Ambrosia dumosa* burs; and *Lepidospartum squamatum* achenes for treatments that showed significant differences from the control. Germination was complete at the end of 14 days for all species except *Larrea divaricata* and *Lepidospartum squamatum*, which were respectively complete at the end of 21 and 8 days.

Larrea divaricata Unhulled and Hulled Seeds. Thiourea, 15-hour soaking, and activated carbon significantly improved 7-day germination and speeded initiation of germination of *L. divaricata* hulled and unhulled seeds, with the thiourea treatment continuing to improve germination significantly through the 14th day, and the 15-hour soaking giving significant benefit through the 21st day on unhulled seeds (Fig. 1, top left). The 15-hour soaking result confirms results of Barbour (1968). Both 4-hour 80 C and 6% sodium hypochlorite treatments significantly decreased germination throughout the 21 days, the 4-hour 80 C delaying germination initiation by 6 days. In all these treatments, germination was considerably greater at 21 days than at 14 days. Germination would probably have been complete at the end of the 14th day for most of the treatments if germination had been initated at 26 C, which is closer to the optimum temperature for this species (Barbour 1968). The 3-hour soaking, 4-hour 60 C heat, stratification, hydrogen peroxide, 0.5% sodium hypochlorite, and 100-ppm and 1000-ppm ethylene treatments (not shown) did not affect germination sig-

Table 1. Treatments used on species studied.

Treatment*	Larrea divaricata (unhulled)	Larrea divaricata (hulled)	Atriplex polycarpa	Atriplex canescens	Hymenoclea salsola	Ephedra nevadensis	Ambrosia dumosa	Lepidospartum squamatum
Scarification	–	–	+	+	–	–	–	–
4 hours, 60C	+	–	+	+	+	+	+	+
4 hours, 80C	+	–	+	+	+	+	+	+
Stratification	+	–	+	+	+	+	+	–
Activated carbon	+	+	+	+	+	+	+	–
3 hours soaking	+	+	+	+	–	–	–	–
15 hours soaking	+	+	+	+	–	–	–	–
100 ppm ethylene	+	+	+	–	–	–	–	–
1000 ppm ethylene	+	+	+	+	–	–	–	–
Hot water, 5 min	+	–	+	+	–	–	–	–
0.5% sodium hypochlorite	+	+	+	+	–	–	–	–
6% sodium hypochlorite	+	+	+	+	–	–	–	–
3% thiourea	+	+	+	+	–	–	–	–
6% hydrogen peroxide	+	+	+	+	–	–	–	–

* Treatments used on each species are indicated by a plus sign.

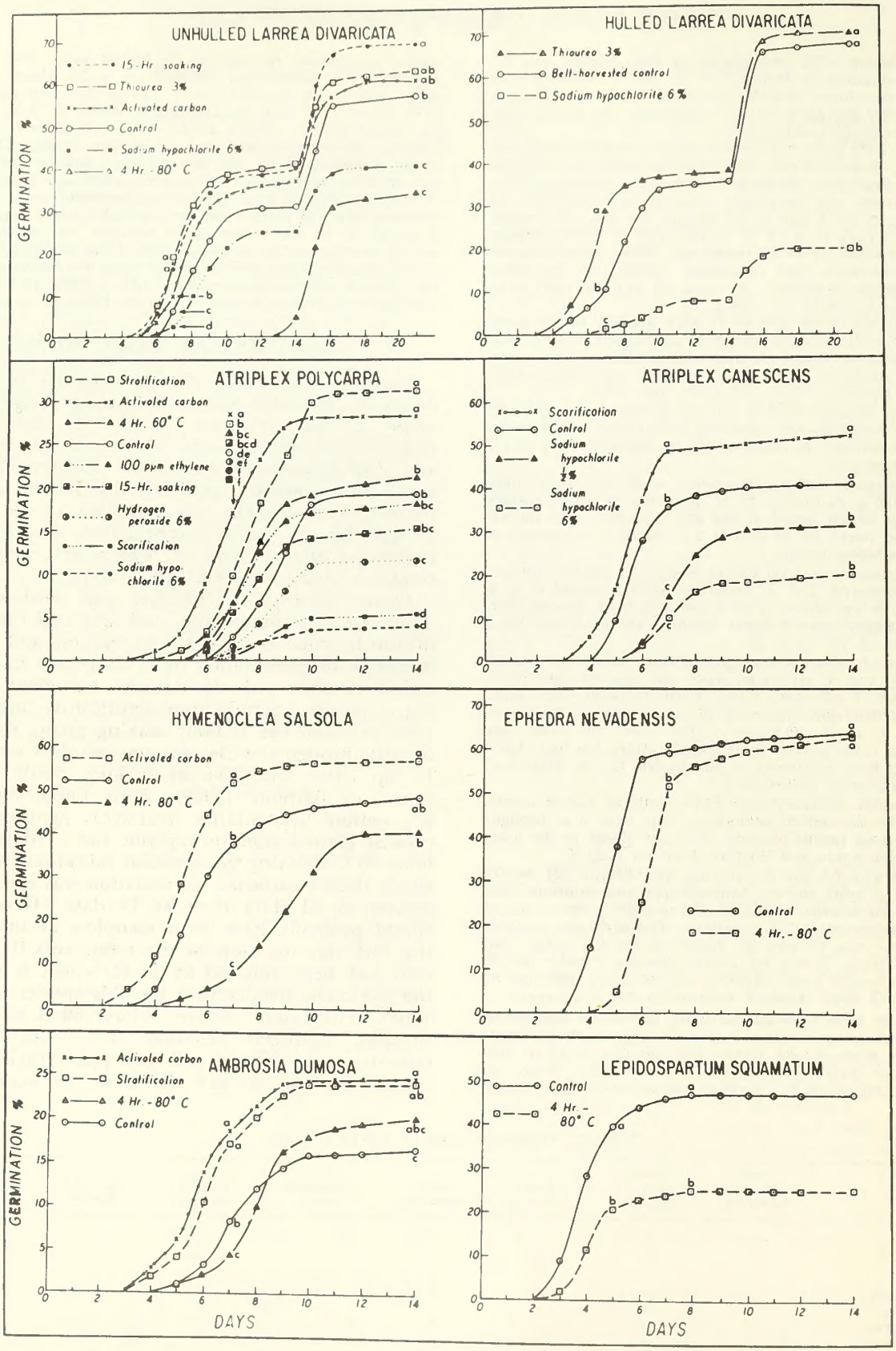

Fig. 1. Germination of seeds, fruits, burs, and achenes, representing treatments that showed significant differences from the control. Temperatures were increased from 21 C to 26 C on the 14th day for *Larrea*. Germinations at days indicated by the same letter are not different according to Duncan's NMRT ($P < 0.05$).

nificantly; the hot-water treatment destroyed all viability.

Belt-threshed seeds of *Larrea divaricata* were used in subsequent tests. Only thiourea significantly improved 7-day germination as well as speeding initiation of germination (Fig. 1, top right). No method significantly improved 14 or 21-day germination, although 6% sodium hypochlorite decreased germination at 7, 14, and 21 days. The treatments with activated carbon, 3-hour soaking, 6% hydrogen peroxide, 0.5% sodium hypochlorite, 15-hour soaking, and 100 or 1,000 ppm ethylene did not affect germination significantly. The lack of response to activated carbon (not shown) could be deceiving, because radicles protruded during treatment and some germinating seeds died in the drying-out process. The fact that 15-hour soaking improved the germination of unhulled seeds but not of hulled seeds allows speculation that the pericarp is inhibitory. Comparison of the control treatments reinforces this deduction (56 vs. 68% at 21 days).

Thus, drilling hulled seed treated with thiourea may assure a quick germination and emergence from fruit otherwise difficult to seed. This would be a valuable asset in an arid environment where surface soil moisture is available only during short periods following rains.

Atriplex polycarpa Fruits. Activated carbon was the best treatment for speeding initiation of germination of *A. polycarpa* fruits (4 days vs. 7 days for control) as well as significantly increasing 7 and 14-day germination (Fig. 1, second row left). Stratification also speeded initiation of germination as well as increasing 7 and 14-day germination significantly. In addition, the 4-hour 60 C and the 100-ppm ethylene treatments significantly increased 7-day germination. The 4-hour 60 C results correspond to results of Chatterton (1970). Sodium hypochlorite (6%), scarification, and hydrogen peroxide reduced germination significantly, with the first two treatments giving the most severe reduction. Hot water (not shown) killed the embryos. Treatments of 3-hour soaking, 4-hour 80 C heat, thiourea, 0.5% sodium hypochlorite, and 1,000 ppm ethylene (not shown) had no effect on germination. The utricles are postulated as partially inhibitory since the activated carbon was effective in speeding and improving germination. Activated carbon need not be used as a presceding treatment; instead, it could be mixed directly with the utricles in the drill box during the drilling operation in early winter.

Atriplex canescens Fruits. Germination (10%) of untreated *A. canescens* fruits proved to be quite good (Fig. 1, second row right). Only the scarification treatment significantly improved 7-day germination. No treatment improved 14-day germination. Activated carbon (not shown) considerably speeded initiation of germination (2 days vs. 5 days for the control) but did not improve 7-day germination. Stratification, thiourea, and 6% hydrogen peroxide and 1000 ppm ethylene (not shown) also improved germination initiation. Both 0.5 and 6% sodium hypochlorite decreased germination. The hot-water treatment (not shown) completely destroyed viability. Treatments that had no significant effect on germination were 3-hour soaking, 4-hour 60 and 80 C heat, 1,000 ppm ethylene, and 15-hour soaking (not shown). The activated carbon and scarification results lead to the conclusion that the bracts are partially inhibitory to germination. Again, as with *Atriplex polycarpa* utricles, the activated carbon treatment could be implemented by mixing it with the utricles during the drilling operation to speed emergence in early winter.

Hymenoclea salsola Fruits. Activated carbon improved the initiation of germination of *H. salsola* fruits and significantly improved 7-day germination (Fig. 1, third row left). The 4-hour 80 C treatment decreased 7-day germination but had no effect on 14-day germination. The 80 C treatment slowed germination but did not destroy viability. The 4-hour 60 C and stratification treatments had no effect on germination.

Ephedra nevadensis Seeds. The 4-hour 80 C treatment slowed the germination of *E. nevadensis* seeds but did not depress 14-day germination or viability (Fig. 1, third row right). Although the seeds were subjected to stratification and activated carbon, no germination tests were performed because radicle protrusion had occurred by the end of the treatment period (30 days). Radicle protrusion of 5 to 8 mm had occurred on 76% of the seeds from the stratification and on 71% of the seeds from the activated carbon. The 4-hour 60 C treatment (not shown) did not affect germination.

Ambrosia dumosa Burs. Both 7- and 14-day germination of *A. dumosa* burs were improved by stratification and activated carbon treatments (Fig. 1, lower left). Again the 80 C treatment slowed germination but did not decrease 14-day germination. The 4-hour 60 C heat (not shown) did not affect germination. Dormancy may be more of a problem than inhibition in this species since both stratification and activated carbon were quite similar in effects on final germination (both 24%). One would not expect germination to be improved beyond that attained by these two treatments; bur fill was only 26%.

Lepidospartum squamatum Achenes. One would not expect any treatment to improve germination of *L. squamatum* since normal germination (47%) approximated achene fill. The two heat treatments were made in order to test their effect on depressing germination. The 4-hour 80 C treatment reduced both 5- and 8-day germination (Fig. 1, lower right). The 4-hour 60 C (not shown) did not affect germination.

We conclude that:

1. Activated carbon was the most consistent in improving early germination. Germination was speeded in all six species treated. From a practical point of view, this treatment need not precede seeding but could be applied to the seed before sowing.

2. Next-most effective treatments in speeding and improving 7-day germination were thiourea on *Larrea divaricata* fruits and seeds, and stratification on *A. polycarpa* and *Ambrosia dumosa* seeds.

3. The 15-hour soaking treatment was effective on fruits of *Larrea divaricata*, thus pointing out that

an inhibitor may limit germination and that belt-thresher hulling may therefore be beneficial.

4. Six percent sodium hypochlorite and 4-hour 80 C reduced early germination and total germination, and boiling water destroyed the viability of the three species tested.

5. Tolerance to the frequent high temperatures of the Mojave Desert habitat is reflected in the fact that germination was not depressed in any species by 4-hour 60 C heat applied to the fruit.

LITERATURE CITED

Barbour, M. G. 1968. Germination requirements of a desert shrub, *Larrea divaricata*. Ecology 49:915-923.

Chatterton, N. J. 1970. Physiological ecology of *Atriplex polycarpa:* growth, salt tolerance, ion accumulation, and soil-plant-water relations. Ph.D. dissertation, Univ. Calif., Riverside. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 31: 4632-B).

Cornelius, D. R., and L. O. Hylton. 1969. Influence of temperature and leachate on germination of *Atriplex polycarpa*. Agron. J. 61:209-211.

Duncan, D. S. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Knipe, D., and C. H. Herbel. 1966. Germination and growth of some semidesert grasslands species treated with aqueous extract from creosote bush. Ecology 47:775-781.

Nord, E. C., and G. R. Van Atta. 1957. Germination of fourwing saltbush seed improved by scarification and grading. U.S. Forest Service, Calif. Forest and Range Exp. Stn. Res. Note 125, Berkeley. 5 p.

———, and G. R. Van Atta. 1960. Saponin—a seed germination inhibitor. Forest Sci. 6:350-353.

Springfield, H. W. 1970. Germination and establishment of fourwing saltbush in the southwest. US Forest Serv., Rocky Mts. Forest Range Exp. Sta. Research Paper RM-55, Ft. Collins, Colorado, 48 p.

Twitchell, L. T. 1955. Germination of fourwing saltbush seed as affected by soaking and chloride removal. J. Range Manage. 8:218-220.

Williams, W. A., O. D. Cook, and B. L. Kay. 1974. Germination of native desert shrubs. Calif. Agric. 28 (8):13.

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Appendix II

Revegetation of Disturbed Sites with Native Shrub Species in the Western Mojave Desert

Walter L. Graves

ABSTRACT

It is often difficult to establish shrubs (either native or introduced on sites under xeric (arid) climatic conditions. Information is needed on proper species and revegetation techniques where natural vegetation has been removed by man's activities on disturbed sites in southern California deserts.

Revegetation treatments were designed to test the effect of supplementary irrigation on stand establishment of five native Mojave Desert shrub species, Ambrosia dumosa (Gray) Payne (white bursage), Atriplex canescens (Pursh.) Nutt. (fourwing saltbush), Atriplex polycarpa (Torr.) Wats. (desert saltbush), Larrea tridentata (Sesse & Moc. ex. DC.) Cov. [L. divaricata] (creosote bush), and Lepidospartum squamatum (Gray) Gray (scalebroom); comparisons of transplanting nursery stock with direct seeding; and adaptability to two different sites along the west side of the Mojave Desert.

A. canescens was successfully seeded and transplanted at both test sites, with an average spot stocking establishment after 2 years and 4 months of 48% and a transplant survival of 23%. Ambrosia dumosa, transplanted following the coldest winter period (in February), was successfully established from nursery-grown seedlings at both test sites, with established stocking varying from 42 to 54%. A. polycarpa was successfully established from nursery seedlings at one of the two test sites, with a 28% establishment stocking. Both Ambrosia and A. polycarpa had poor establishment from seeding at both test sites, with the Ambrosia spot stocking establishment varying from 0 to 4% and the A. polycarpa from 0 to 12%. Larrea tridentata and Lepidospartum squamatum had poor seeding and transplant establishment ability at both test sites, with Larrea spot seeding showing no survival and only transplant stocking establishment at one test site of 12%, while Lepidospartum had a seeding and transplant establishment (4%) at only one site. A one-time irrigation treatment did not improve spot seeding or transplant establishment of any of the five species at either of the two test sites. Neither test site had any significant influence on establishment. Nursery "hardening" procedures and transplanting weather conditions proved to be more critical for transplant survival than drought during establishment.

Certain of the five shrub species can be established successfully in this arid climate by proper timing (preceding the season of major rainfall expectation) of seeding and transplanting.

REVEGETATION OF DISTURBED SITES WITH NATIVE SHRUB SPECIES IN THE WESTERN MOJAVE DESERT

Walter Graves

More and more, man's population pressures, technological activities, and search for recreation cause him to expand into ecosystems where nature is in a precarious balance. The deserts of southern California, notably the Mojave Desert, are undergoing activities (off-road vehicle and right-of-way construction) which are often destructive to native shrub vegetation. A conspicuous example, construction and right-of-way clearing for the second Los Angeles aqueduct, prompted the study on revegetation possibilities described herein.

It is often difficult to establish shrubs (either native or introduced) on sites under xeric (arid) climatic conditions. Seeding or revegetation failures reported by researchers in Arizona, New Mexico, and the Great Basin have been attributed to low seed germination, poorly adapted seed source, planting at the wrong depth or time of year, poor growing conditions, inadequate seedbed preparation, the removal of seeds or clipping of plants by rabbits and rodents, competition with resident vegetation, and poorly matched soil type (Wilson, 1928; Cassady and Glendening, 1940; Bridges, 1941; Reynolds, Lavin and Springfield, 1949; Plummer, Christensen and Monsen, 1968; Springfield, 1970; and Cable, 1972). Probably the most critical factor is soil moisture during and after germination or planting (Holmgren, 1954; and Aldon, 1972). Since rainfall distribution patterns certainly play a role in plant establishment, shrub revegetation deserves study in California's semiarid and arid regions where the rainfall distribution pattern is more Mediterranean than continental.

This study deals with five native shrub species: Ambrosia dumosa (Gray) Payne [Franseria d.] (white bursage), Atriplex canescens (Pursh.) Nutt. (fourwing saltbush), Atriplex polycarpa (Torr.) Wats (desert saltbush), Larrea tridentata (Sesse & Moc. ex. DC.), Cov. [L. divaricata] (creosote bush), and Lepidospartum squamatum (Gray) Gray (scalebroom). Of these, Revegetation trials have been reported only for A. canescens and A. polycarpa.

A. canescens was reported (Nord, Hartless and Nettleton, 1971) to have been spot-seeded successfully at 1090 m (3600 ft) and 1515 m (5000 ft) elevation [58 cm (23 in.) and 80 cm (32 in.) average rainfall, respectively], and A. polycarpa at 1090 m (3600 ft) elevation in the San Jacinto Mountain Range in southern California. Those results indicate a better stand from early-spring seeding at shallow depths 12.5 mm (1/2 in.) than from midwinter seeding and a seeding depth of 25 mm (1 in.). A. canescens had better stand survival than A. polycarpa, though stand vigor differed significantly among strains (seed source location). Love and McKell (1966), Love, Kay, McKell, and Goodin (1968), and Love and Kay (1969), reporting on species adaptation trials in the Temblor Range of southern California with 15 to 17.5 cm (6 to 7 in.) rainfall conditions at approximately 900 m (3000 ft) elevation, indicate erratic seeding results with both A. canescens and A. polycarpa from both early-winter and spring seeding, although water-leaching of seeds gave substantially better seedling establishment of both species. An early publication by Kraebel (1936) recommended fall seeding of A. canescens, as one of many possible species for spot seeding for erosion control on roads in the southern California semiarid and desert interior at elevations up to 900 m (3000 ft).

Seeding trials of A. canescens led to variable recommendations for New Mexico, Arizona, and the Great Basin, where summer rainfall is an important part of total yearly precipitation. For New Mexico conditions, Bridges (1942) recommended seeding 16 to 17 kg/ha (10 to 15 lb/ac) during the period from September to January. Springfield and Housley (1952) updated that recommendation from trials in New Mexico by stating that seeding approximately 6.6 kg/ha (6 lb/ac) of viable utricles during the spring to midsummer period was the most successful. They emphasized that "success of seeding depends largely on the amount and seasonal distribution of precipitation during the period when temperatures are favorable for germination and establishment; these conditions prevail most consistently in spring and midsummer in New Mexico." As for seeding rates, Springfield (1970) concluded from various recommendations (Wilson, 1928 and 1931; Van Dersal, 1938; Bridges, 1942; United States Forest Service, 1948; Springfield and Housley, 1952) that 4.4 to 8.8 kg/ha (4 to 8 lb/ac) of de-winged seeds or 8.8 to 17.5 kg/ha (8 to 15 lb/ac) of winged seeds be seeded less than 25 mm (1 in.) deep, and that some seedbed preparation is desirable. In addition, straw mulching at a 900 kg/ha improved seedling establishment approximaely 180% (Springfield, 1972).

Transplanting is more costly than seeding but is reported to be highly successful in establishing A. canescens in New Mexico (Springfield, 1970; and Aldon, 1970a, b, 1972). Springfield (1970) reports that survival of transplants in the 2nd and 3rd years was 50 to 100% and recommends planting into moist soil of seedling 15 cm (6 in.) or greater in height (seedlings 8 weeks old or more). Aldon (1970a, 1972) obtained 66 to 83% first-year survival of transplants and recommended planting 4 to 6-week-old plant-band nursery seedlings in late July or early August following rain or when the soil is moist (1/3 to 2 atms. water tension at 5-in. sampling depth).

Cable (1972), working on sites of creosote bush and mesquite-burroweed in southern Arizona at about 970 m (3200 ft) elevation where annual precipitation was 34 cm (13.5 in), obtained 3-year-old stand survival of A. canescens from transplants and seeding. Transplanting into moist soil in December and early January gave much higher survival rates on creosote bush sites, and creosote bush removal or kill by grubbing was more beneficial for A. canescens plant survival than picloram (1 lb aehg water) foliar-applied spray. January seeding of de-winged seed at 11 kg/ha (10 lb/ac) had a much higher survival rate at the end of 3 years on the creosote bush site than the mesquite-burroweed site (1605 plants/ha vs. 114 plants/ha). Both spraying with picloram and grubbing to eliminate competition from creosote bush improved A. canescens survival from seeding. Spot seeding proved to be the poorest of the three revegetation methods.

Plummer et al (1968) made extensive studies on shrub revegetation, including A. canescens, in Utah. Stands of A. canescens were reported to be better from fall or winter broadcast seeding, although spring seedings have been successful. The recommendation for seed covering is 12.5 mm (1/2 in.) or less. Early spring seedling transplanting is usually successful, though later transplanting can succeed if the soil can be kept moist. Guinta, Christensen and Monsen (1975) used a browse seeder equipped with scalper to eliminate competition from cheatgrass (Bromus tectorum) during seeding in December, successfully establishing A. canescens, alone or in mixtures with other shrub species, at a site in Utah of 1730 m (5700 ft) elevation and 27.5 cm (11 in.) annual precipitation.

Outside the United States, A. canescens, as an introduced species, is reported to be highly promising for revegetation of overgrazed range and salt-affected soils in cold arid and semiarid areas of North Africa (Franclet and Le Houerou, 1971) and in the Middle East (Naveh, 1972), although no results were given concerning successful revegetation methods.

Of a more general nature, since A. canescens is a highly palatable browse plant, stand establishment often depends on protection of the seedlings against rabbits, rodents, and other wildlife, as stressed by Wilson (1928), Cassidy and Glendening (1940), Bridges (1941), Plummer et al. (1968), Springfield (1970), and Cable (1972).

Revegetation trials have been much less extensive with A. polycarpa than with A. canescens, although it too is recognized as a very valuable native browse plant. Mention has been made previously of seeding trials by Nord et al. (1971), Love and McKell (1966), and Love et al. (1968) on A. polycarpa in conjunction with the A. canescens. Cornelius and Hylton (1969) extrapolated their germination results on A. polycarpa seeds to recommend late February or March seeding of leached seeds in the Panoche Hills area of California (western side of the southern part of the Great Valley). Chatterton (1970) found that A. polycarpa seeds germinate and seedlings become established over a wide range of fluctuating temperatures (3-11 C to 21-28 C). From field observations on natural seedling phenology in the Temblor Range area, he reported that germination occurred during the late February period when the temperature extremes averaged near 16 C and 2 C. Sankary and Barbour (1972) report that December seeding in the Temblor Range area was a total failure even though A. polycarpa occurred in native stands near the seeding site. Low rainfall (115 mm during the seeding year) and heavy competition with introduced naturalized annuals (Bromus rubens and Erodium cicutarium) were given as possible cause for the negative results. McMillan (1960) reported that personnel of the California Department of Fish and Game were sometimes able to reestablish A. polycarpa for game cover by hand-broadcasting seed at 112 kg/ha (100 lb/ac) on smooth plowed land in late January. One of the evident results of the establishment trials with Atriplex spp. can be summarized by saying that general agreement is lacking as to the best time for seeding any saltbushes. More information is needed on revegetation methods for native shrubs in arid environments.

A seed mixture of the five species treated in this study, plus seeds of Hymenoclea salsola and Ephedra nevadensis, was seeded at 5 locations along the second Los Angeles aqueduct (western Mojave Desert) by rangeland drill at 11 kg/ha (10 lb/ac) in early summer, 1972, but no evaluation of the stand establishment has been published (Burgess L. Kay, personal communication).

This study was initiated to obtain information on revegetation possibilities of five native shrub species on disturbed sites in the western Mojave Desert.

MATERIALS AND METHODS

In September of 1972, a nursery (greenhouse) operation was begun in Davis to start seedlings of the shrub species for field plantings. Five native Mojave Desert species were chosen for the revegetation study. Since

a major part of the west side of the Mojave Desert zone, through which the Los Angeles aqueduct runs, is predominant by creosote bush scrub with Larrea tridentata and Ambrosia dumosa species dominating, those two species were chosen, plus two shrubs of important browse value, A. canescens and A. polycarpa, that occur in this zone mostly in washes, ravines, and alkali soils. The fifth species, Lepidospartum squamatum, was chosen since it seems able to colonize disturbed sites along the right-of-way of the adjacent first Los Angeles aqueduct.

Seeds for growing the transplants and for the seeding treatments were part of samples used in earlier laboratory germination and seed treatment trials (Williams, Cook and Kay, 1974). These collections were made by a commercial seed collector along the west side of the Mojave Desert at aproximately 900 m (3000 ft) elevation from December 1970 to October 1971, and provided to us through the Bureau of Land Management. The seeds had been in cold storage (10 C) since March 1972. Seed age at the time of the fall 1972 greenhouse seeding was 15 months for Ambrosia dumosa, 21 months for A. canescens and A. polycarpa, 13 months for Larrea tridentata, and 11 months for Lepidospartum squamatum.

The soil mix for the transplant bands (by weight 86% sand, 8.5% silt, 5% clay, and 0.5% organic matter), was made from sand, Yolo loam soil, and spaghum moss to approximate soil texture in the field. Commercial fertilizer (16-20-0-15) was added to the mix at 1.2 kg/m (2 lb/yd). Final bulk density was 1.3 grams/cm .

Open-ended reusable plastic bands, measuring 6.4 x 6.4 x 17.8 cm high (2.5 X 2.5 X 7 in.), were filled with the soil mix to 2.5 cm of the top, and enough seeds or fruits (burs for Ambrosia dumosa, utricles for A. canescens, seeds for A. polycarpa, belt-harvested hulled seeds for Larrea tridentata, and akenes for Lepidospartum squamatum) to produce four seedlings (based on germination tests) of each species, was placed in each band and covered lightly (6 mm). Wooden flats, which held 35 bands, were placed on tables inside the greenhouse, and frequent light watering was done during the first 3 weeks of germination and initial seedling development. Because seedling survival of Lepidospartum squamatum proved difficult to obtain, UC soil mix 50:50 (Matkin and Chandler 1957) was used to replace the initial soil mix for this species. Approximately 200 plant bands per species were started to provide the transplants needed for the trial. Within 2 to 4 weeks of emergence, each band was thinned to one plant to allow maximum development of the seedling before field transplanting Day-night temperatures in the greenhouse varied from 32 C to 21 C during the first four weeks, and gradually reached the range of 27 C to 16 C in the final weeks of greenhouse growth. In the last four weeks before field transplanting the hardening process was initiated by placing the seedlings outside the greenhouse, exposed to Davis December weather. The day-night temperature range during the hardening period was 10 to -7 C. This hardening process was too severe for the Ambrosia dumosa seedlings, resulting in 80% mortality, so additional bands were set up in December 1972 to start seedlings of this species for later transplanting. Greenhouse growing conditions were similar, but the two-week hardening period was warmer, varying from 14 C to 4 C. In the final week of December 1972, all surviving seedlings of the five species were hauled by pick-up truck, with the plants partially protected by a tarpaulin covering, to the western Mojave Desert planting sites. The later Ambrosia dumosa seedlings were hauled in the second week in February 1973. At transplanting, seedling ages were 2 months for Ambrosia

dumosa (February planting) and Lepidospartum squamatum, and 3 months for A. canescens, A. polycarpa, and Larrea tridentata. Average seedling height at transplanting was 17.8 cm (7.0 in.) for A. dumosa, 14.0 cm (5.5 in) for A. canescens, 11.4 cm (4.5 in) for A. polycarpa, 5.7 cm (2.2 in.) for Larrea tridentata, and 5.0 cm (2.0 in.) for Lepidospartum squamatum. Seedling root growth at transplanting of all species had reached the plant-band bottom of 15 cm (6 in.).

Sites for the revegetation trials were selected in conjunction with the Bureau of Land Management personnel (LaVern Walgren). Two sites were chosen along the right-of-way of the 2nd Los Angeles Aqueduct on public land supervised by the Bureau of Land Management. At each site, areas of approximately 0.28 ha (0.69 ac) were fenced with partially buried chicken wire and top-strand barbed wire to a height of 1.37 m (4.5′) to protect against wildlife (rabbits) and domestic animals.

The two sites, designated Mojave and South Freeman, were respectively approximately 9.6 km (6.0 miles) north and 59.2 km (37.0 miles) northeast of the town of Mojave (Kern County). Exact location of the Mojave site in the Mojave Quadrangle (15 minute topographic series) is T32S, R35E, S24 at 35 08′ N and 118 10′ W, 975 m (3200′) elevation, and the South Freeman site is T27S, R37E, S26 at 35 34′ N and 117 58′ W in the InyoKern Quadrangle, 1027 m (3370′) elevation. The Mojave site is on a southeast-facing 4.5% slope, and the South Freeman site is on a southeast-facing 4% slope, both on alluvial fans. According to the Soil Conservation Service (Cal Hill, personal communication) both sites approximate the Arizo gravelly loamy sand series, 0 to 5% slopes, and by the current system of classification are classed in the sandy-skeletal, mixed, thermic family of Typic Torripsamments and Entisols order (Woodruff, McCoy and Sheldon, 1970). These soils are in mixed alluvium derived chiefly from granitic rock, excessively drained, very low in fertility (0.6% organic matter), available waterholding capacity of 0.04-0.05 cm water/cm soil, neutral to mildly alkaline with depth, and cobbly and very gravelly loamy sand to a depth of 152 cm (60 in.) or more.

Laboratory analysis of soil samples from the two sites indicates that the Mojave site varies in soil paste pH from 7.6 (0-15 cm) to 7.8 (75-90 cm depth) (Jackson, 1958). Electrical conductivity varied from 0.7 mmhos/cm (25 C) at the surface 15 cm to 0.4 mmhos at the 75-to-90-cm depth, which would classify the soil as nonsaline (Richards, 1954). Texture was consistently loamy sand throughout the profile from the top 15 cm to the 90-cm depth, but approached the sand texture with texture analysis of the less than 2 mm fraction from the surface 15 cm, giving 86.5% sand, 10% silt, and 3.5% clay (American Society of Testing Materials 1973, and U.S. Department of Agriculture 1951). Sodium-bicarbonate-extractable phoshorus of the surface 15 cm was 6 ppm (Olsen and Dean 1965). The South Freeman site soil paste pH varied from 7.5 (0-15 cm) to 7.2 at the depth of 75 to 90 cm. Electrical conductivity varied from 0.6 mmhos/cm at the surface to 1.9 mmhos/cm at the 90 cm depth. Although higher in soluble salts, this soil is also classed as nonsaline. The texture was quite similar to that at the Mojave site, with a consistent loamy sand-sand profile to 90-cm depth. The surface 15 cm soil less than 2 mm fraction contained 87% sand, 10% silt, and 3% clay. Sodium-bicarbonate-extractable phosphorus in the surface 15 cm was 3.5 ppm

Both of the sites were located on the denuded part of the 100-m right-

of-way clearing of the late 1960's. These scarred areas had been ripped to a depth of approximately 25 cm on one-meter centers as part of a rehabilitation program to provide a better environment for revegetation by either artificial or natural means. Soil moisture was monitored during the study period on both planting sites and adjacent undisturbed vegetated area to evaluate this factor. At each stand evaluation count, soil samples were taken at 15-cm intervals to 90-cm depth, brought to the laboratory, and over-dried at 105 C, and percent moisture (dry weight basis) was calculated (Richards 1954).

Vegetation along each site is creosote bush scrub with Joshua trees showing up occasionally along the South Freeman site. Larrea tridentata and Ambrosia dumosa dominate the vegetation at both sites. In addition, the Mojave site v egetation contains species of Eriogonum fasciculatum spp. polifolium and Ephedra nevadensis distributed sparsely over the area, with species of Salazara mexicana, Hymenoclea salsola, Acamptopappus sphaerocephalus spp. hirtellus, and A. polycarpa occurring mostly in washes and drainage areas. Both Lepidospartum squamatum and Isomeris arborea occur on disturbed soils in the general area. Stipa speciosa and Oryzopsis hymenoides occur occasionally throughout the area. A vegetation study at each site consisted of sixteen 43-m line transects for measuring shrub canopy cover (Canfield 1941), and 10 plots of 30 x 30 m for determining shrub density. Total shrub canopy cover at the Mojave site was 20.8% (11.6% Larrea tridentata, 8.5% Ambrosia dumosa, and 0.7% Eriogonum fasciculatum, Ephedra nevadensis, Salazara mexicana, Hymenoclea salsola, and Acamptopappus sphaerocephalus). Plant density estimates gave 311 Larrea plants per ha, 1320 Ambrosia plants per ha, 405 Eriogonum plants per ha, and 11 miscellaneous species per ha, giving a total shrub density of 2147 per ha. Winter and early spring annuals in 1973 were dominated by Erodium cicutarium, Bromus rubens, and Amsinkia tessellata. The South Freeman site had a total shrub canopy cover of 22.0% (11.4% Larrea, 7.2% Ambrosia, 1.4% Acamptopappus, and 2% Hymenoclea salsola, Ceratoides lanata, Grayia spinosa, Lycium cooperi, Opuntia spp., Tetradymia spp., Aster abatus, and Yucca brevifloria). Plant density estimates were 267 Larrea per ha, 825 Ambrosia per ha, 130 Acamptopappus per ha, and 210 miscellaneous species per ha, giving a total shrub density of 1432 per ha. Spring annuals were dominated by Amsinkia tessellata, with minor quantities of Erodium circutarium and Bromus rubens.

The plant climate of both sites is classified as middle-elevation desert-plant climate Zone 3 of arid moderate to cool temperate air-drained slopes and is in the Subzone 3.1 adjacent to the main valleys (Mathias, Metcalf, Kimbell, Hemstreet, Gilbert and Davis 1968). The precipitation is mostly in December to March, with 90% of yearly average precipitation from November through April. The summer months are usually hot and dry, with occasional thunderstorms of high rainfall. Snowfall is infrequent, and strong winds are frequent in winter. The mean monthly minimum temperature, 0-1.6 C (29.1 F), occurs in January, and the mean monthly maximum temperature is 39 C (102.1 F), in July (Luvisi, Gilbert and Peterson 1967). According to U.S. Dept. of Commerce (1958 and 1964) climatic summaries for 1931 through 1960, high variability in annual rainfall is common in the area with the Mojave Station representative of a mean precipitation of 127 mm (5.02 in.) and an annual precipitation range of 43 mm (1.68 in.) to 399 mm (15.71 in.). From the isohyetal map of the U.S. Dept. of Interior (1969) the estimated mean annual precipitation for the Mojave site is 203 mm (8 in.) and 178 mm (7 in.) for the South Freeman site.

From rain gauges installed by the Bureau of Land Management along the aqueduct at each seeding site rainfall was recorded during the study period.

Revegetation treatments were designed to test the effects of watering on stand establishment, the relative value of transplanting and direct seeding, and adaptability to different site locations. Table 1 summarizes these treatments and seed characteristics. The individual plots were designed to have spot seeding or transplants 2 m apart in rows, with plot rows 2.5 m apart. At 100% stocking the average area to be occupied per plant would be 5 m and average plant density would be 2000 plants per hectare. The number of surviving seedlings per species dictated the number of transplants available per treatment. Transplant number per treatment varied from 2 to 6 seedlings per species. Spot seedings per treatment varied from 4 to 6 spots per species. All transplant and spot-seeding treatments were replicated four times and completely randomized at each site, except for the A. canescens, Larrea tridentata, and Lepidospartum squamatum one-time-watered transplant treatment, which had 8 replications. Initially a transplant treatment was planned with a second watering operation scheduled for June 1973, but because of favorable winter and spring rainfall conditions this operation was canceled, leaving an extra four replications similar to the one-time-watered transplant treatments.

Planting treatments for the Ambrosia dumosa, A. canescens, A. polycarpa, and Larrea tridentata species were spot-seeding one-time-irrigated, spot-seeding no-watering control, transplants one-time-irrigated, and no-watering control for both the sites. Treatments for Lepidospartum squamatum were similar except that the transplant treatments were canceled at the South Freeman site because of insufficient transplants.

Work of Chan, Harris, Leiser, Paul and Fissel (1971) served as a guide for site preparation of the spot seeding and transplant holes, fertilizer use, irrigation, seeding rate, and seed coverage. Holes were prepared by soil auger to depths of 15 cm (6 in.) for the transplants and 7.5 to 10 cm (3-4 in.) for the seed spots. Hole diameter at the soil surface was about 15 cm (6 in.). Fertilizer, in the form of slow-release MagAmp , 7-40-6, and gypsum (20% sulfur), was applied respectively at the bottom of each hole at the rate of 15 grams (30 kg/ha) and 5 grams (10 kg/ha). The seedlings of each species were placed in the prepared holes, and soil was gently filled in around the seedlings and plant band, keeping the soil mix intact while the plastic plant band was slowly removed for reuse. The soil was firmed around the transplant, leaving a depression of about 12 to 18 mm (1/2-3/4 in.). For the spot seeding treatments, the soil was firmed back into the hole, and a predetermined number of seeds or fruits of each species was placed in the seeding depression of 6 to 12 mm, and covered by firming the soil to a depth of about 2 times the seed diameter. Seeding rate per spot was 18 fruits of Ambrosia dumosa, 10 fruits of A. canescens, 22 fruits of A. polycarpa, 10 belt-harvested hulled thiourea-treated seeds of Larrea tridentatam, and 10 fruits of Lepidospartum squamatum. The Larrea tridentata seeds were hulled with a belt harvester, treated with a 3% thiourea solution for 5 min. and allowed to dry on the seeds before seeding. This treatment had been found to improve initiation of germination in the laboratory (Graves, Kay, and Williams 1975). Seed coverage was about 2 mm for A. polycarpa, 4 mm for A. canescens and Lepidospartum squamatum, 4.5 mm for Ambrosia dumosa, and 6 mm for Larrea tridentata.

Table 1. Summary of Revegetation Treatments made at Mojave and S. Freeman Test Sites, Seeding Rate and Seed Germination

Species	Treatments		Site location	Planting date	No. of trans-plants or seed pockets/ applica-tion	No. of repli-cations per site	No. of seeds or fruits/ pocket & (rate/ha)	Average seed or fruit size (mm)	Germ-ina-tion summer 1972 %
Ambrosia dumosa	seed spots	Control-no irrigation	Mojave	12/29/72	6	4			
			S.Freeman	1/2/73	6	4			
		one time irri-gation at plt.	Mojave	12/29/72	6	4	18 fruits (0.12kg/ha)	2.2 mm (fruit)	16
			S.Freeman	1/2/73	6	4			
		Control	S.Freeman	2/11/73	6	4			
	trans-plant	no irrigation	Mojave	2/11/73	4	4			
		one time irri-gation at plt.	S.Freeman	2/11/73	6	4			
			Mojave	2/11/73	4	4			
Atriplex canes-cens	seed spots	Control-no irrigation	Mojave	12/29/72	4	4			
			S.Freeman	1/2/73	4	4			
		one-time irri-gation at plt.	Mojave	12/29/72	4	4	10 fruits (0.67 kg/ha)	2 mm (seed)	40
			S.Freeman	1/2/73	4	4			
	trans-plant	Control-no irrigation	Mojave	12/29/72	4	4			
			S.Freeman	1/1/73	2	4			
		one-time irri-gation at plt.	Mojave	12/29/72	4	8			
			S.Freeman	1/1/73	2	8			
Atriplex poly-carpa	seed spots	Control-no irrigation	Mojave	12/29/72	4	4			
			S.Freeman	1/2/73	4	4			
		one-time irri-gation at plt.	Mojave	12/29/72	4	4	22 fruits (0.037 kg/ha)	1 mm (seed)	13
			S.Freeman	1/2/73	4	4			
	trans-plant	Control-no irrigation	Mojave	12/29/72	4	4			
			S.Freeman	1/1/73	2	4			
		one-time irri-gation at plt.	Mojave	12/29/72	4	4			
			S.Freeman	1/1/73	2	4			
Larrea triden-tata	seed spots	Control-no irrigation	Mojave	12/29/72	6	4			
			S.Freeman	1/2/73	6	4			
		one-time irri-gation at plt.	Mojave	12/29/72	6	4	10 seeds[1] (0.11 kg/ha)	3 mm (seeds)	38
			S.Freeman	1/2/73	6	4			
	trans-plant	Control-no irrigation	Mojave	12/29/72	6	4			
			S.Freeman	1/1/73	4	4			
		one-time irri-gation at plt.	Mojave	12/29/72	6	8			
			S.Freeman	1/1/73	4	8			
Lepidospartum squama-tum	seed spots	Control-no irrigation	Mojave	12/29/72	6	4			
			S.Freeman	1/2/73	6	4			
		one-time irri-gation at plt.	Mojave	12/29/72	6	4	10 fruit (0.02 kg/ha)	2 mm (fruit)	47
			S.Freeman	1/2/73	6	4			
	trans-plant	Control-no irrigation	Mojave	12/29/72	6	4			
		one-time irri-gation at planting	Mojave	12/29/72	6	8			

[1] 3% thiourea treated seeds (belt-harvester shelled)

Water was applied at two liters per transplant or spot seeding for all species of the one-time-irrigated treatment. A temporary collar placed around the transplant and the spot seeding allowed the two liters to be applied and infiltrated over a 15-cm (6 in.) circular area. Half of the once-watered treatments (both transplants and spot seeded) received the two-liter irrigation of a 0.1% solution by weight of "SSO Anti-Stress Agent," a product containing 10% sarsaponin by weight as an active ingredient, reported by various workers to promote seed germination and vegetative growth (Balansard and Pellissier, 1944, 1945).

Stand counts were made on April 17, 1973, to determine seedling emergence from spot seeding and transplant survival. A second and third stand count was made on June 22, 1973, and December 15, 1973, and on March 25, 1975, about two years after seedling emergence, a final stand count was made to determine plant survival. During the second stand count, seed spots stocked with more than one seedling were reduced to a single seedling per spot. When seedling emergence and plant survival count were sufficient to satisfy minimum-expectations criteria, chi-square analysis was used to test for differences between treatments, planting sites, the time or period during which seedling survival counts were significantly reduced, and sarsaponin effect (Cochran 1954). Plant heights were monitored each time plant counts were made, and foliar height was measured on all surviving plants at the time of the final plant count. Flowering and seed production were observed during the monitoring period.

RESULTS AND DISCUSSION

Artificial revegetation from spot seeding and transplanting varied widely among the five shrub species on the Mojave and South Freeman sites. The poor emergence or transplant survival from several of the treatments yielded insufficient data for statistical comparisons. Transplant survival from the late-December early-January planting was very poor (<25%) for all species at the South Freeman site and very poor for Larrea tridentata and Lepidospartum squamatum at the Mojave site. A very high (>90%) mortality during the first planting period caused this planting of Ambrosia dumosa seedlings to be abandoned, whereas the second planting (in February 1973) had a relatively low transplant mortality. Both "hardening" conditions and transplanting weather conditions were severe and caused seedling mortality of all species, with the South Freeman site suffering the most damage. In addition to high gusty winds and snow flurries during this period, temperature lows for the Mojave station of -12 C to 2 C were recorded over a period of eight days (January 1-8) in 1973. Thus the low survival of transplant seedlings of Lepidospartum squamatum and Larrea tridentata at both sites and poor transplant survival of A. polycarpa and A. canescens at the South Freeman site could be attributed more to transplanting weather conditions than the first year's summer dry period following transplanting. This factor makes somewhat questionable the statistical comparisons of transplant treatments for these species. In several instances survival was zero or so low that the counts did not meet criteria for chi-square analysis (Cochran 1954). Table 2 summarizes the spot seeding and transplant treatments results of the five species at the Mojave and S. Freeman test sites.

Rainfall in the initial growing season of December 1972 through June 1973 was respectively 179 mm (7.06 in.) and 135 mm (5.32 in.) at the Mojave

Table 2. Transplant survival, seed spot emergence, interim plant survival, and plant establishment for different treatments of five species planted at Mojave and South Freeman test sites, average plant height, and flowering and seed production observations.

Species	Observation date	Mojave												S. Freeman											
		Treatment								Chi-square analysis for homogeneity of treatments stocking counts (1)			Observations on flower or fruit production	Treatment								Chi-square analysis for homogeneity of treatments stocking counts (1)			Observation on flower or fruit production
		Seed spots				Transplants								Seed spots				Transplants							
		One-time irrig. (SW)		Control (S)		One-time irrig. (TW)		Control (T)		(SW) vs. (S)	(TW) vs. (T)	(SW&S) vs. (TW&T)		One-time irrig. (SW)		Control (S)		One-time irrig. (SW)		Control (S)		(SW) vs. (S)	(TW) vs. (T)	(SW&S) vs. (TW&T)	
		Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)					Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)				
Ambrosia dumosa	4/17/73	0	--	4	(2)	75	(2)	69	(2)	1.02	0.15	44.53**	--	0	(2) --	4	(2)	58	(2)	58	(2)	1.02	0.01	36.0**	--
	6/22/73	0	--	4	(2)	62	12.7	62	10.6	--	--	--	--	0	--	4	5.1	50	15.2	54	15.2	--	--	--	--
	12/15/73	0	--	4	7.6	44	20.3	50	19.2	--	--	--	seed on 25% of (T) plts	0	--	4	7.2	42	25.4	54	20.2	--	--	--	No flower or seed prod.
	3/25/75	0	--	4	27.9	44	25.6	44	23.4	1.02	0.01	21.9**	--	0	--	0	--	42	32.0	54	25.4	(3)	0.75	28.9**	"

Mojave versus S. Freeman Site

Seed spots pooled data (3)		Transplant data (pooled)(TW&T)
4/15/73	--	0.99
3/25/75	--	0.02

Table 2. Transplant survival, seed spot emergence, interim plant survival, and plant establish-ment for different treatments of five species planted at Mojave and South Freeman test sites, average plant height, and flowering and seed production observations. (continued)

Species	Mojave												S. Freeman										
	Observation date	Treatment: Seed spots One-time irrig. (SW) Stocked (%)	Average plant height (cm)	Control (S) Stocked (%)	Average plant height (cm)	Transplants One-time irrig (TW) Stocked (%)	Average plant height (cm)	Control (T) Stocked (%)	Average plant height (cm)	Chi-square analysis for homogeneity of treatments stocking counts[1] (SW) vs. (S)	(TW) vs. (T)	(SW&S) vs. (TW&T)	Observations on flower or fruit production	Treatment: Seed spots One-time irrig. (SW) Stocked (%)	Average plant height (cm)	Control (S) Stocked (%)	Average plant height (cm)	Transplants One-time irrig. (SW) Stocked (%)	Average plant height (cm)	Control (S) Stocked (%)	Average plant height (cm)	Chi-square analysis for homogeneity of treatments stocking counts[1] (SW) vs. (S)	(TW) vs. (T)	(SW&S) vs. (TW&T)	Observation on flower or fruit Production
Atriplex canescens	4/17/73	50	3.0	75	3.0	31	(2)	19	(2)	2.13	1.22	9.93**	--	81	(2)	62	(2)	19	(2)	12	(2)	1.25	1.14	10.08**	--
	6/22/73	50	10.2	56	12.7	28	22.9	19	15.2	--	--	--	--	75	12.9	44	11.4	19	30.5	12	38.1	--	--	--	--
	12/15/73	38	30.5	56	40.6	28	45.7	19	33.0	--	--	--	seed on 16% of (SW) 11% (S)&(TW) plants	62	38.1	44	33.5	19	66.0	12	61.0	--	--	--	no flower or seed product.
	3/25/75	31	57.4	56	52.6	28	74.9	19	55.7	2.03	0.50	3.07	--	62	55.9	44	51.3	19	84.6	12	71.1	2.00	1.14	3.87**	

Mojave versus S. Freeman site

Seed spot data pooled (SW & S)		Translant data pooled (TW & T)
4/17//73	0.01	0.47
3/25/75	0.01	0.25

Table 2. Transplant survival, seed spot emergence, interim plant survival, and plant establish-ment for different treatments of five species planted at Mojave and South Freeman test sites, average plant height, and flowering and seed production observations. (continued)

Species	Observation date	Mojave												S. Freeman									
		Treatment								Chi-square analysis for homogeneity of treatments stocking counts[1]			Observations on flower or fruit production	Treatment								Chi-square analysis for homogeneity of treatments stocking counts[1]			Observation on flower or fruit production
		Seed spots				Transplants								Seed spots				Transplants							
		One-time irrig. (SW)		Control (S)		One-time irrig. (TW)		Control (T)		(SW) vs. (S)	(TW) vs. (T)	(SW&S) vs. (TW&T)		One-time irrig. (SW)		Control (S)		One-time irrig. (SW)		Control (S)		(SW) vs. (S)	(TW) vs. (T)	(SW&S) vs. (TW&T)	
		Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)					Stocked (%)	Average plant height (cm)	Stocked (%)	Average Plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)				
Atriplex polycarpa	4/17/73	12	(2)	12	(2)	31	(2)	25	(2)	0.01	0.15	2.41	--	0	--	12	(2)	12	(2)	0	--	0.68	(3)	(3)	--
	6/22/73	12	15.2	6	12.7	31	10.2	25	35.6	--	--	--	--	0	--	6	10.2	0	--	0	--	--	--	--	--
	12/15/73	12	22.9	6	20.3	31	38.1	25	48.3	--	--	--	seed on 20% of (TW)& 25%(T)	0	--	6	--	6	35.6	0	--	0	--	--	no flower or seed prod.
	3/25/75	12	61.0	6	40.6	31	60.5	25	66.5	0.37	0.15	3.69	--	0	--	6	53.3	0	--	0	--	1.06	(3)	(3)	"

Mojave versus S. Freeman site

Seed spot data pooled (SW&S)		Transplant data[3]
4/17/73	0.24	
3/25/75	1.00	

Table 2. Transplant survival, seed spot emergence, interim plant survival, and plant establish-ment for different treatments of five species planted at Mojave and South Freeman test sites, average plant height, and flowering and seed production observations. (continued)

Species	Observation date	Mojave Treatment: Seed spots One-time irrig. (SW) Stocked (%)	Mojave Treatment: Seed spots One-time irrig. (SW) Average plant height (cm)	Mojave Treatment: Seed spots Control (S) Stocked (%)	Mojave Treatment: Seed spots Control (S) Average plant height (cm)	Mojave Treatment: Transplants One-time irrig. (TW) Stocked (%)	Mojave Treatment: Transplants One-time irrig. (TW) Average plant height (cm)	Mojave Treatment: Transplants Control (T) Stocked (%)	Mojave Treatment: Transplants Control (T) Average plant height (cm)	Mojave Chi-square analysis for homogeneity of treatments stocking counts[1]: (SW) vs. (S)	Mojave Chi-square analysis for homogeneity of treatments stocking counts[1]: (TW) vs. (T)	Mojave Chi-square analysis for homogeneity of treatments stocking counts[1]: (SW&S) vs. (TW&T)	Mojave Observations on flower or fruit production	S. Freeman Treatment: Seed spots One-time irrig. (SW) Stocked (%)	S. Freeman Treatment: Seed spots One-time irrig. (SW) Average plant height (cm)	S. Freeman Treatment: Seed spots Control (S) Stocked (%)	S. Freeman Treatment: Seed spots Control (S) Average plant height (cm)	S. Freeman Treatment: Transplants One-time irrig. (SW) Stocked (%)	S. Freeman Treatment: Transplants One-time irrig. (SW) Average plant height (cm)	S. Freeman Treatment: Transplants Control (S) Stocked (%)	S. Freeman Treatment: Transplants Control (S) Average plant height (cm)	S. Freeman Chi-square analysis for homogeneity of treatments stocking counts[1]: (SW) vs. (S)	S. Freeman Chi-square analysis for homogeneity of treatments stocking counts[1]: (TW) vs. (T)	S. Freeman Chi-square analysis for homogeneity of treatments stocking counts[1]: (SW&S) vs. (TW&T)	S. Freeman Observation on flower or fruit production
Lepidospartum squatum	4/17/73	50	[2]	38	[2]	0	--	17	[2]	0.76	5.59*	23.20**	--	8	[2]	12	[2]	NO TREATMENTS			[3]	NO TREATMENT	--
	6/22/73	35	5.1	25	3.8	0	--	8	7.6	--	--	--	--	0	--	4	2.5						--
	12/15/73	0	--	8	4.4	0	--	8	11.4	--	--	--	No flower or seed product.	0	--	0	--						--
	3/25/75	0	--	8	27.9	0	--	8	34.3	2.08	1.60	0.17	"	0	--	0	--				[3]		--

Mojave versus S. Freeman site[3]

(1) Chi-square 2 x 2 analysis, 1 df.
(2) Data not determined
(3) Insufficient data for analysis
* Means counts differ significantly ($P < 0.05$)
** Means counts differ highly significantly ($P < 0.01$)

Table 2. Transplant survival, seed spot emergence, interim plant survival, and plant establish-ment for different treatments of five species planted at Mojave and South Freeman test sites, average plant height, and flowering and seed production observations. (continued)

Species	Observation date	Mojave												S. Freeman									
		Treatment								Chi-square analysis for homogeneity of treatments stocking counts[1]			Observations on flower or fruit production	Treatment								Chi-square analysis for homogeneity of treatments stocking counts[1]			Observation on flower or fruit production
		Seed spots				Transplants								Seed spots				Transplants							
		One-time irrig. (SW)		Control (S)		One-time irrig. (TW)		Control (T)		(SW) vs. (S)	(TW) vs. (T)	(SW&S) vs. (TW&T)		One-time irrig. (SW)		Control (S)		One-time irrig. (SW)		Control (S)		(SW) vs. (S)	(TW) vs. (T)	(SW&S) vs. (TW&T)	
		Stocked (%)	Average plant height (cm)	Stocked (%)	Average Plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)					Stocked (%)	Average plant height (cm)	Stocked (%)	Average Plant height (cm)	Stocked (%)	Average plant height (cm)	Stocked (%)	Average plant height (cm)				
Larrea tridentata	4/17/73	0	--	0	--	17	(2)	21	(2)	(3)	0.19	7.94**	--	4	(3)	0	--	0	--	6	(2)	(3)	(3)	(3)	--
	6/22/73	0	--	0	--	15	6.7	17	5.1	--	--	--	--	4	2.5	0	--	0	--	0	--	--	--	--	--
	12/15/73	0	--	0	--	12	19.0	12	8.9	--	--	--	No flower or seed prod.	0	--	0	--	0	--	0	--	--	--	--	--
	3/25/75	0	--	0	--	12	27.4	12	26.2	(3)	0.01	4.80*	"	0	--	0	--	0	--	0	--	(3)	(3)	(3)	--
		Seed spot data[3]								Mojave versus S. Freeman site				Transplant data[3]											

and South Freeman sites. The high precipitation month was February, with 98 mm (3.87 in.) at the Mojave site and 53 mm (2.08 in.) at the South Freeman site. No rain was recorded at either site from June 1973 to November 1973. The November 1973 through June 1974 rainfall was respectively 143 mm (5.64 in.) and 108 mm (4.26 in.) at Mojave and S. Freeman. Precipitation during the last observation year (July 1974 to March 1975) was respectively 70 mm (2.77 in.) and 82 mm (3.23 in.) at Mojave and S. Freeman. Fortunately, precipitation during the growing season of the trial planting (December 1972 through June 1973) approximated average rainfall for both of the sites, although still considered low (179 mm and 135 mm) for conventional "dryland" planting conditions.

The periodic monitoring of the soil-profile (0 to 90 cm) moisture regime (soil sampled on 1/1/73, 2/10/73, 4/15/73, and 6/23/73) revealed favorable moisture conditions throughout the growing period from the planting date to the June 1973 survival count. At the Mojave site, average soil moisture in the upper 90 cm was consistently 36 to 44% greater in the ripped are than in adjacent undisturbed bare areas of the creosote bush vegetation. At the S. Freeman site also, average soil moisture during this period was greater on the ripped site than in the undisturbed bare area between shrubs in the adjacent vegetation. Although the actual difference in soil moisture in the 0-to-90-cm depth was 3.4 to 3.9%, this represents approximately 42 to 49% of the available water-holding capacity of the soil. The effect on plant establishment of the more favorable moisture condition in the ripped sites was not evaluated, but could certainly be assumed to be positive.

Ambrosia dumosa seeding and transplanting. The spot-seeding seedling emergence of this species was very poor at both test sites (0 to 4% stocking at the Mojave and S. Freeman sites), and the one-time irrigation did not improve seedling emergence. The relatively good germination vigor compared with that of other shrub species of this region (Williams et al. 1974) would lead one to expect better germination and emergence than these results indicate. Seed quality could have been a factor, which might have been partially compensated for if the number of fruits per seed spot had been increased. Following the initial failure to obtain viable nursery seedlings for field transplanting, the results of the second transplanting in February 1973 were quite good. Important factors were more favorable nursery "hardening" conditions (day-night range of 14 to 4 C) and site planting conditions. Soil moisture approximated field capacity at both sites during the February 1973 transplanting operation, and thus was ideal for transplanting. Initial seedling survival of the transplants as measured by the 4/17/73 observation, averaged respectively 73 and 58% at the Mojave and S. Freeman test sites, a difference not statistically significant ($P < 0.05$). Transplant establishment, as measured by the 3/25/75 observation, remained good, respectively 44 and 48% at Mojave and S. Freeman (no difference statistically). The one-time irrigation did not improve transplant initial survival or establishment at either site. Transplanting was significantly ($P < 0.01$) better than the spot seeding method for establishing this species at both test sites. Chi-square analysis (change of level of mean) of the pooled transplant survival data following the initial survival of 4/17/73 indicates that no period was significant in reducing survival count at either of the test sites. No site differences were detected in transplant initial survival and establishment. Seed production occurred on 25% of the plants of the transplant control treatment during the first year's growth at the Mojave site, while no flowering or seed production was observed at the S. Freeman site during the entire study period, thus possibly pointing out a subtle

difference betweeen the two test sites in soil, temperature, or rainfall conditions. Average transplant height during the 6/23/73 observation is less than the average height at transplanting (11.6 cm vs. 17.8 cm at the Mojave site and 15.2 cm vs. 17.8 cm at the S. Freeman site). Animal cropping and plant dieback had preceded this observation date.

A. canescens seeding and transplanting. This species was considerably superior to the others in ability to establish from spot seeding. In fact, seedling emergence was significantly ($P < 0.01$) better for spot seeding than for survival of transplants on 4/17/73 at both test sites, and significantly ($P < 0.05$) better for plant establishment at the S. Freeman site. At the Mojave site, seedling emergence for pooled seed spots was 62.5% compared with 25% for transplant survival, and at S. Freeman these comparisons were respectively 71 and 16%. Stand establishment from the spot treatments continued to be superior to the transplant treatments at the Mojave site, with 44% survival versus 24%, and continued significantly superior at the S. Freeman site, with 53% survival versus 16%. The one-time-irrigation treatments did not significantly improve seedling emergence and establishment or transplant survival. It is interesting that at the final monitoring date (2 years and 4 months after planting) the spot seeding treatments continue to lag behind, though approaching, the transplant treatments in average plant height at the Mojave site (54.3 cm vs. 69.9 cm) and at the S. Freeman site (54.0 cm vs. 77.8 cm). At the Mojave site, seed production occurred during the first season's growth on 16% of the one-time-irrigated spot-seeding plants, 11% of the spot-seeding control plants, and one-time-irrigated transplants, although no seed or flower production occurred throughout the monitoring period at the S. Freeman site. No significant difference between the two sites was detected from the spot-seeding or transplants treatments. Analysis for survival counts (change of level of the mean plant counts) during the monitoring period found no period from 4/17/73 to 3/25/75 significant in reducing survival counts at either of the two sites. Stand establishment percent for spot seeding approaches that obtaind by Nord et al. (1971) with much more favorable soil and moisture conditions.

Atriplex polycarpa seeding and transplanting. Seedling emergence was poor with spot seeding at both sites, respectively 12 and 6%, at Mojave and S. Freeman. The transplanting treatments at the Mojave site provided higher average survival and establishment than the spot-seeding treatments (survival 28% vs. 12%, and establishment 28% vs. 9%). This difference was not significant, although the chi-square statistic for establishment count comparison was 3.69, which represents a chi-square level (5.66%) approaching 5% significance. At the S. Freeman site both spot seeding and transplanting gave very poor seedling emergence and survival. The S. Freeman site transplant data were not analysed statistically since observations during the planting period indicated high seedling mortality before transplanting. This factor caused few seedlings, of probably poor quality, to remain for transplanting use. Also, survival counts were insufficient for chi-square analysis. Site differences between the spot-seeding pooled-treatments results were not signifant. Seedling survival following emergence and transplant survival following initial transplanting mortality were excellent at the Mojave site. Thus, analysis of the survival counts indicated that no period was significant in reducing survival during the monitoring period from 4/17/73 to 3/25/75. Because of animal cropping of several plants of the one-time-irrigated transplant treatment at Mojave preceding the 6/22/73 observation date, average plant height (10.2 cm) was lower

than the average seedling height (11.4 cm) at transplanting. Average plant height at the final observation date from spot seeding (54.9 cm) approached that of the transplant treatments (63.2 cm). As with Ambrosia and A. canescens, seed production occurred during the first growing season and attained 20% of the one-time-irrigated transplants and 25% of the transplant control treatment plants, and no flowering or seed production was observed during the study period at the S. Freeman site.

Larrea tridentata seeding and transplanting. Spot-seeding emergence was totally absent at the Mojave site, and survival was absent at both sites with only 4% seedling emergence at the S. Freeman site. Since seedling emergence was not improved by fruit shelling and thiourea, some discretion must be applied in extrapolating the results of laboratory seed treatments to field conditions. These results and deduction from findings of Kay (1975) and Williams et al. (1974) in depth-of-planting studies on this species indicated that very poor seedling emergence (<1%) occurs with late-fall and winter seeding whereas late-spring seeding can give excellent emergence (>80%) from the 1-cm depth, thus again demonstrating the warm-temperature requirements for germination of this species (Barbour 1968). Revegetation of this species in this area may be limited to years with irregular late-spring or summer thunderstorm, a requirement that makes germination and survival of seedlings of this species rare events (Barbour 1969). This germination requirement makes planned artificial revegetation of Larrea under natural rainfall in this zone a very risky operation. The transplant treatments were of very moderate success at the Mojave site, with pooled data on transplant treatments showing a 19% transplant survival and 12% stand stocking establishment. The one-time irrigation did not significantly improve transplant survival or establishment at the Mojave site. The absence of spot-seeding emergence made transplanting at the Mojave site significantly ($P < 0.01$) better than spot seeding for seedling survival, and significantly ($P < 0.05$) better for stand establishment. Plant development was slow compared with the Atriplex species, and no flowering or seed production occurred during the observation period. The lack of plant survival from the seed spot treatments at the Mojave site and from the seed spot and transplant treatments at the S. Freeman site provided insufficient data for statistical analysis of site comparisons. As with the Atriplex polycarpa transplant seedlings, mortality was high preceding transplanting at the S. Freeman site, and transplant seedlings were of poor quality.

Lepidospartum squamatum seeding and transplanting. This species proved to be the most difficult of the five species to establish. Not only were nursery seedlings difficult to grow and "harden" for transplanting, but field survival was extremely poor. Spot seeding at the Mojave site provided good seedling emergence (44%) but very poor survival (4%). The one-time irrigation did not significantly improve seedling emergence or establishment at the Mojave site. Transplant seedling survival was extremely poor, but seedling quality was so poor (from transport and harsh-weather shock) that the S. Freeman transplant treatments were canceled. Although seedling emergence at the Mojave site was significantly ($P < 0.01$) better for spot seeding than for the transplant treatments, initial survival is of little importance since average plant establishment from both spot seeding and transplanting was only 4%. At the S. Freeman site, spot seeding gave poor seedling emergence (10%) and no plant survival. Unlike with the other four species, plant mortality at the Mojave site was high following seedling emergence count, and the dry summer and fall period from 6/22/73 to 12/15/73

was a significant ($P < 0.01$) influence in reducing plant counts for spot pooled treatments. Plant development was the slowest of the five species, and no flowering or seed production occurred during the study period. One could question the choice of this species for artificial revegetation of xeric sites in this area.

In general, in spite of the difference in the rainfall during the initial growing period from January 1973 through June 1973, plant establishment of all species was statistically similar at both test sites in March of 1975. Only the subtle difference of seed production occurring on Ambrosia dumosa, A. canescens, and A. polycarpa plants at the Mojave site suggests a possible difference in environmental factors between the two sites. Poor seedling emergence or survival of all species except A. canescens and the nonhardiness of the transplants of A. polycarpa, Larrea tridentata, and Lepidospartum squamatum probably limited the usefulness of this study to point out the effect of site differences for plant establishment, if any. Although no particular importance has been attributed to the value of the enclosures to protect against wildlife and domestic-animal browsing during establishment, it is believed that this played an important part in stand establishment and growth of the highly valued browse species A. canescens and A. polycarpa.

Effect of Sarsaponin on Plant Establishment. Table 3 summarizes sarsaponin effects on plant establishment. Excluding the treatments where emergence or survival was too low to justify statistical analysis, data were still sufficient to indicate that the sarsaponin treatments, except on the A. canescence transplants at the Mojave site, did not significantly improve seedling emergence or plant survival. Even the significant ($P < 0.05$) improvement in establishment of A. canescens transplants was lower (44%) than for the spot-seeding no-irrigation control (56%) at the Mojave site.

CONCLUSIONS

This study, though of limited scope, shows artificial revegetation to be feasible on xeric sites under low rainfall. The principal tentative conclusions are:

1) If seeding or transplanting is timed to precede the season of the major part of precipitation, such as late fall or early winter in this region of the Mojave Desert, stand establishment without irrigation can be as successful as with a supplemental one-time-irrigation at planting.

2) A. canescens can be successfully direct-seeded or transplanted in early winter without irrigation if some protection against browsing is provided during the initial 2 to 3 years of stand establishment. Direct seeding would be the most logical method except on extremely harsh or difficult-access sites, for it is relatively low in cost and requires less site preparation than when starting with nursery-grown seedlings.

3) Both Ambrosia dumosa and A. polycarpa can be transplanted successfully into sites of the western Mojave Desert where some soil moisture is available. Late January or early February plantings would be logical since the long periods (one or two weeks) of the winter low temperatures (below freezing) are normally past.

Table 3. Effect of Sarsaponin on Transplant Survival, Seed Spot Emergence and Plant Establishment from one-time-irrigated treatments of all species at two test sites (Mojave and South Freeman)

Species and one-time irrigated treatments	Site: Mojave						Site: South Freeman					
	Control		Sarsaponin		Chi-square		Control		Sarsaponin		Chi-square	
	Initial survival 4/17//73 %	Established on 3/25/75 %	Initial survival 4/17/73 %	Established on 3/25/75 %	Initial survival count	Established count	Initial survival 4/17/73 %	Established on 3/25/75 %	Initial survival 4/17/73 %	Established on 3/25/75 %	Initial survival count	Established count
Ambrosia dumosa												
Seed spots	0	0	0	0	1/	1/	0	0	0	0	1/	1/
Transplants	75	50	75	38	0.01	0.34	58	33	58	50	0.01	0.69
Atriplex canescens												
Seed spots	50	50	50	12	0.01	2.62	75	50	88	75	0.41	1.06
Transplants	19	12	44	44	2.33	3.86*	12	12	25	25	0.41	0.41
Pooled	29	25	46	33	1.42	0.40	48	31	56	50	0.16	1.02
Atriplex polycarpa												
Seed spots	0	0	25	25	2.28	2.28	0	0	0	0	1/	1/
Transplants	38	38	25	25	0.14	0.14	0	0	0	0	1/	1/
Larrea tridentata												
Seed spots	0	0	0	0	1/	1/	8	0	0	0	1/	1/
Transplants	17	12	17	12	0.01	0.01	0	0	0	0	1/	1/
Lepidospartum squamatum												
Seed spots	33	0	67	0	2.67	1/	8	0	8	0	0.01	1/
Transplants	0	0	0	0	1/	1/	No treatment					
All species												
Seed spots	15	8	27	6	2.07	0.15	15	15	15	12	0.01	0.44
Transplants	20	15	24	19	0.33	0.40	20	12	25	20	0.29	0.83
Pooled	18	12	25	14	1.81	0.14	17	20	10	15	0.14	1.24

1/ Insufficient data for chi-square analysis

* Means counts differ significantly by the chi-square analysis ($P < 0.05$), 2 x 2 table, 1 df.

4) Both Larrea tridentata and Lepidospartum squamatum are difficult to establish by either direct seeding or transplanting.

5) If nursery-grown transplants are the only way of ensuring revegetation of harsh sites, utmost attention should be given to proper "hardening" and transplanting during favorable weather.

6) Chemicals such as sarsaponin applied through irrigation, even though they demonstrate protection against soil moisture stress or improvement in germination, may have limited usefulness since supplementary irrigation may not be necessary to ensure stand establishment for this type of site rehabilitation.

While it may be highly desirable for esthetic compatability to consider revegetation of disturbed sites in this or any other region, with the "dominant" species that make up the adjacent vegetation, one may have to design seed mixes with species that are comparable with artificial reestablishment methods and that provide maximum assurance of stand survival. Other native shrub species should be screened for revegetation potentials in this region.

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LITERATURE

Aldon, Earl F. 1970a. Growing fourwing saltbush transplants for field planting. USDA Forest Service, Rocky Mtn. Forest Range Ex. Sta. Research Note RM-166, Ft. Collins, Colo., 3 p.

_____. 1970b. Fourwing saltbush can be field planted successfully. USDA Forest Serv., Rocky Mtn. Forest Range Exp. Sta. Research Note RM-173, Ft. Collins, Colo., 2 p.

_____. 1972. Critial soil moisture levels for field planting fourwing saltbush. J. Range Management 25:311-312.

American Society for Testing and Materials. 1973. Annual Book of ASTM Standard, Philadelphia. Part 11; 201-213.

Balansard, J. and F. Pellissier. 1944. Action of Quillaya saponin on isolated embryos of wheat. (in French) Societe de Biologie de Marseille Proc. 138:622.

_____. 1945. Saponins and growth of Solanum lycopersicum L. (in French). Societe de Biologie de Marseille Proc. 139:111.

Barbour, M. G. 1968. Germination requirements of the desert shrub Larrea divaricata. Ecology 49:915-923.

_____. 1969. Age and space distribution of the desert shrub Larrea divaricata. Ecology 50:679-685.

Bridges, J. O. 1941. Reseeding trials on arid rangelands. New Mexico Agr. Exp. Sta. Bull. 278, 48 p., illus.

_____ 1942. Reseeding practices for New Mexico ranges. New Mexico Agr. Exp. Sta. Bul. 291. 48 p., illus.

Cable, Dwight R. 1972. Fourwing saltbush revegetation trials in southern Arizona. J. Range Mgmt. 25:150-153.

Canfield, R. 1941. Application of the line interception method in sampling range vegetation. J. For. 39:388-394.

Cassady, J. T. and G. E. Glendening. 1940. Revegetation semidesert rangelands in the southwest. U. S. Civ. Conserv. Corps Forest Publ. 8, 22 p., illus.

Chan, F. J., R. W. Harris, A. T. Leiser, J. L. Paul and R. E. Fissell. 1971. Establishment of woody plants by direct seeding in California. Final Report, Division of Highways, Dept. of Transportation, State of California. (Agreement No. RTA 13945-13069 UCD).

Chatterton, N. J. 1970. Physiological ecology of Atriplex polycarpa, growth, salt tolerance, ion accumulation, and soil-plant-water relations. Ph.D. dissertation, Univ. Calif., Riverside. Univ. Microfilms. Ann Arbor, Mich. (Diss. Abstr. 31:4632-B).

Cochran, William G. 1954. Some methods for strengthening the common (chi-square) tests. Biometrics 10:417-451.

Cornelius, Donald R. and L. O. Hylton. 1969. Influence of temperature and leachate on germination of Atriplex polycarpa. Agron. J. 61:209-211.

Franclet, A. and H. N. Le Houerou. 1971. Atriplex species in Tunisia and North Africa. (in French). F.A.O. Technical Report 7 (FO:SF/TUN 11), 200 p., illus.

Guinta, Bruce C., Donald R. Christenson and Stephen B. Monsen. 1975. Interseeding shrubs in cheatgrass with a browse seeder-scalper. J. Range Mgmt. 28:398-402.

Graves, W. L., B. L. Kay, and W. A. Williams. 1975. Seed treatment of Mojave Desert shrubs. Agron. J. 67:773-777.

Holmgren, Ralph C. 1954. A comparison of browse species for revegetation of big-game winter ranges in southwestern Idaho. U.S. Forest Service Intermountain Forest and Range Exp. Sta. Res. Paper 33. Ogden, Utah, 12 p.

Jackson, M. L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J., pp. 38-56.

Kay, Burgess L. 1975. Test of seeds of Mojave Desert seeds. Appendix II, Progress Report BLM Contract 53500-CT4-2(N).

Kraebel, Charles J. 1936. Erosion Control on Mountain Roads. U.S. Dept. of Agr. Circ. 380, 45 p., illus.

Love, R. Merton, and C. M. McKell. 1966. Temblor Range Research. Annual Report 1965-1966, U. of Calif., Dept. of Agronomy, Davis, Riverside. 53 p.

_____, B. L. Kay, C. M. McKell and J. R. Goodin. 1968. Temblor Range Research. Annual Report 1967-1968. U. of Calif., Depts. of Agronomy-Davis, Riverside. 27 p.

_____,_____, 1969. Temblor Range Research. Annual Report 1968-1969. U. of Calif. Dept. of Agronomy and RS, Davis and Dept. of Agronomy, Riverside, 22 p.

Luvisi, Donald A., D. E. Gilbert and G. D. Peterson, Jr. 1967. Kern County's Climates, Soils, Waters and Crops. U. of Calif. Ag. Ext. Service. 109 p.

Mathias, M. E., W. Metcalf, M. H. Kimball, C. L. Hemstreet, D. E. Gilbert and W. B. Davis. 1968. Ornamentals for California's middle elevation desert. U. of Calif. Agr. Exp. Sta. Bull. 839, Berkeley. 43 p.

Matkin, O. A. and Philip A. Chandler. 1957. The U.C.-type soil mix. Pages 68-85 in Kenneth F. Baker, ed. The U.C. system for producing healthy container-grown plants. U. of California Agri. Exp. Sta. manual 23, Berkeley.

McMillian, I. I. 1960. Propagation of quail brush (saltbush). Calif. Fish and Game 46:507-509, illus.

McMinn, Howard E. 1970. An illustrated manual of California shrubs. U. of Calif. Press, Berkeley, 663 pp.

Munz, Philip A. 1974. A flora of southern California. U. of Calif. Press, Berkeley, 1086 pp.

Naveh, A. 1972. The role of shrubs and shrub ecosystem in present and future Mediterranean land use. Pages 414-427 in C. M. McKell, J. P. Blaisdell and J. R. Goodin, eds. Wildland shrub--their biology and utilization. USDA Forest Service, Intermountain Forest and Range Exp. Sta. General Technical Report Int-1, Ogden.

Olsen, S. R. and L. A. Dean. 1965. Phosphorus. Pages 1035-49 in Black, C. A. ed., Methods of soil analysis, Part 2. Amer. Soc. Agron., Madison, Wisc.

Plummer, A. P., D. R. Christensen, and S. B. Monsen. 1968. Restoring big-game range in Utah. Utah Division Fish and Game Publ. 68-3. 183 p.

Reynolds, H. G., F. Lavin and H. W. Springfield. 1949. Preliminary guide for reseeding in Arizona and New Mexico, USDA Forest Service, Southwest Forest and Range Exp. Sta. Res. Report 7, 14 p.

Richards, L. A., (ed.). 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook 60, Washington, D.C., 160 p.

Sankary, Mohamad Nazir and M.C. Barbour. 1972. Autoecology of Atriplex polycarpa from California. Ecology 53:1155-1162.

Schubert, Gilbert H., L. J. Heidmann and M. M. Larson. 1970. Artificial reforestation practices for the southwest. USDA (Forest Service) Handbook 370, Washington, D.C. 25 p.

Springfield, H. W. 1970. Germination and establishment of fourwing saltbush in the southwest. US Forest Service, Rocky Mtn. Forest Range Exp. Sta. Research Paper RM-55, Ft. Collins, Colo., 48 p.

_____. 1972. Using mulches to establish woody chenopods. Pages 382-391. in C. M. McKell, J. P. Blaisdell and J. R. Goodin, eds. Wildland Shrubs--Their Biology and Utiliation. USDA Forest Service, Intermountain Forest and Range Exp. Sta. General Technical Report Int-1, Ogden.

_____ and R. M. Housley, Jr. 1952. Chamiza for reseeding New Mexico rangelands. USDA Forest Service, Southwest Forest and Range Exp. Sta. Res. Note 122, Tucson, 3 p., illus.

United States Department of Agriculture. 1951. Soil Survey manual. USDA Handbook 18, Washington, D.C. 503 pp., illus.

_____. 1948. Woody plant seed manual. USDA Misc. Pub. 654, Washington, D.C., 416 pp., illus.

United States Dept. of Commerce. 1958. Climatic Summary of the United States Supplement for 1931 through 1952, California. U.S.D.C. Weather Bureau No. 11-4. Washington, D.C. 156 p.

_____. 1964. Climatic Summary of the United States-Supplement for 1951 through 1960. U.S.D.C. Weather Bureau No. 86-4. Washington, D.C., 216 p.

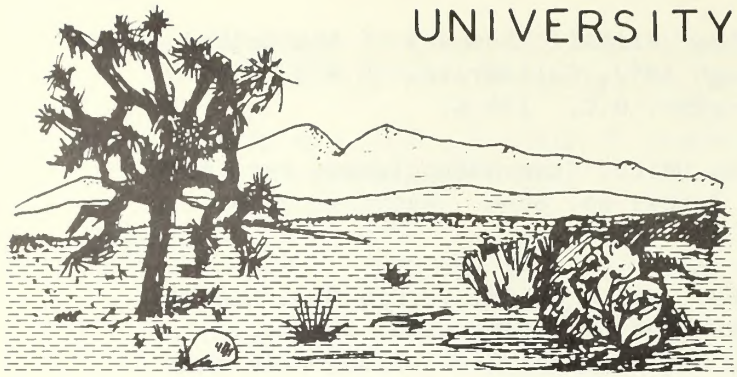
United States Dept. of Interior. 1969. State of California Mean Annual Precipitation Isohyetal Map. Based on USDI Geological Survey, Water Resources Division Report, "Mean Annual Precipitation in the Calif. Region."

Williams, W. A., O. D. Cook and B. L. Kay. 1974. Germination of native desert shrubs. Calif. Agric. 28(8):13.

Wilson, C. P. 1928. Factors affecting the germination and growth of chamiza (Atriplex canescens). New Mexico Agr. Exp. Sta. Bul. 169, 29 pp., illus.

_____. 1931. The artificial reseeding of New Mexico ranges. New Mexico Agr. Exp. Sta. Bul. 189. 37 p.

Woodruff, George A., W. J. McCoy and W. B. Sheldon. 1970. Soil Survey--Antelope Valley Area, California. U.S.D.A. Soil Conservation Service in Coop. with U.C. Ag. Exp. Sta. 187 p.



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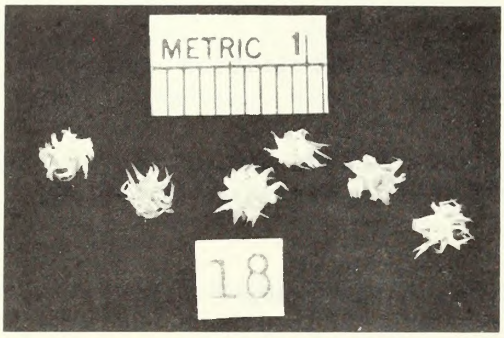
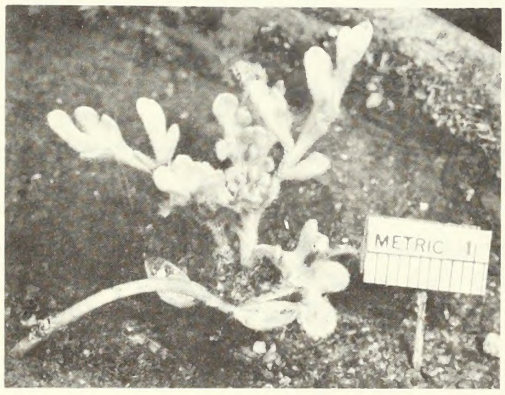
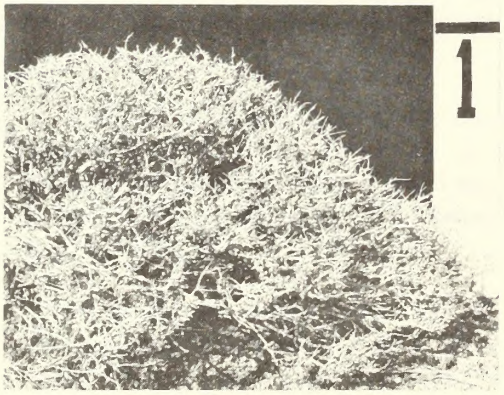
Mojave Revegetation Notes







Ambrosia dumosa (Gray) Payne

[Franseria d. Gray.]

Burrobrush, burroweed, sandbur, white bursage

Family: Asteraceae (Compositae) (Tribe: Heliantheae)

Habit: Low, spreading, rounded, shrub, 30-60 cm high; grayish green; intricately branched white stems, young stems densely short-hairy, interwoven, becoming spinescent with age.

Leaves: Clustered, mostly 1.5-2.0 cm long, 8-11 mm broad; once to thrice-pinnate, with short, rounded lobes; densely short hairy.

Flowers: Inconspicuous; staminate and pistillate heads intermixed in the terminal and lateral spikes of the panicle; staminate heads 3-4 mm in diameter, the free portions of the involucral bracts slightly longer than broad, acute, wooly, pistillate heads, usually with 2-flowered involucres, bracts fused to enclose the seed; flowering primarily Feb. to June and Sept. to Nov., or following rain.

Fruit: Fruiting heads 5-6 mm long, resembling cockleburs; spines broad, thin at bases, with upper surfaces deeply grooved, lower surfaces hooked, tapering at the apices; spines and involucre glandular-puberulent.

Top to bottom: Burs; Seedling showing cotyledons; mature shrub showing effect of browsing.

Abundant on well drained soils through much of the southwest, Ambrosia dumosa is found in Creosote Bush Scrub and Joshua Tree Woodland communities of the Mojave and Colorado deserts of California, from Inyo Co. south and east to Utah, Arizona, Mexico, and lower California (Munz et al. 1959). Coville (1893), in his travels in the Death Valley region, noted that the burrobrush had practically the same altitudinal limits (below 3500 ft (Munz et al., 1959)) as the creosote bush Larrea tridentata, being most common with Hymenoclea salsola in the upper part of the Larrea Belt of the Lower Sonoran Life Zone.

By virtue of its rhizomatous growth habit, similar to that of the creosote bush, Ambrosia is an extremely long-lived shrub (Muller, 1953). The dense, rounded, younger shrubs (about 0.5 m diam.) become irregular as the individual aerial shoots die and an intricate crown of independently rooted shoots develops. This crown accumulates windblown sand and organic debris and allows the clone to spread to about 1 m in diameter. Chase et al. (1966) and Weiland et al. (1971) had no difficulty in vegetatively propagating cuttings of Ambrosia. Lunt et al. (1973) determined that Ambrosia has a soil-oxygen requirement lower than that of Larrea.

The species is predominantly diploid, though chromosome numbers of n = 18, 36, and 54 have been recorded (Payne et al., 1964). The diploid form is that of the typical low, rounded, gray-green shrub described earlier, with delicate 2-3 pinnate leaves and a short spicate inflorescence. The less common polyploid form is a larger, darker-green plant with coarse bipinnate leaves and a much larger inflorescence (Geissman et al., 1968). The dominance of the diploid form supports its placement near the beginning of the evolutionary scheme for the genus (Payne et al., 1964).

Coville (1893) saw that horses preferred Ambrosia over all other desert shrubs for forage in the absence of grass. The shrub is a valuable forage plant on western rangelands, with nutritious burs and foliage (Stark, 1966). Constant trimming by desert animals gives Ambrosia the hedged, founded form common in many areas. Wells noted in Death Valley "The close-cropped, hedged appearance of many Franseria plants in the vicinity of Corkscrew Spring had been puzzling for many years until June 13, 1957, when a chuckwalla was observed to crawl up into a Franseria dumosa bush and, spreading on all four legs, to move about on top of the plant in a sort of swimming motion, snipping off the newer shoots in a hedge-clipping effect. That explained to us for the first time why so many Franserias look the way they do."

Many annual plants appear to be dependent on Ambrosia, being found only under the shrub canopy in spite of a water-soluble toxic principle produced by the shrub that has been found to kill tomato seedlings in nutrient culture (Muller, 1953). The failure of this allelopathic substance was attributed to possible breakdown activity of the soil microflora or adsorption by colloidal components in desert soils. A few of the shrub dependent species are: Malacothrix californica var. glabrata Gray, Rafinesquia mexicana, Phacelia distans var. australis Brand, Ellisia membranaceae Benth, and Chaenactis fremontii Gray.

Information on seed quality is summarized in the following table:

Author	Williams et al., 1974	Kay, 1975A	Kay, 1975B
Collection date	6/71	6/23/73	6/5/74
Seed weight	303,600/kg 138,000/lb	374,000/kg 170,000/lb	161,000/kg 73,000/lb
Purity	-	63%	64%
Fill	27%	16%	44%
Initial germination at	20% @ 17-21 C	8% @ at 20 C	8% @ at 20 C
Plantings in sand: Date	May	November	-
Emergence From 1 cm	16%, 9 days	1%, 20 days	-
Emergence From 2 cm	2%, 10.5 days	0	-

Burs tested by Williams et al. (1974) were collected near Lancaster in early June 1971 by a commercial seed collector. The 1973 sample (Kay, 1975A) was hand collected from late maturing plants along the L.A. Aqueduct by Walter Graves. No cleaning was attempted because of the spiny nature of the burs. The impurities were mainly male flower parts, present because male and female flowers are borne on the same raceme. Collecting burs from beneath the plants is impractical because the light burs are easily windblown, tending to collect under the bush for only a short time. A better harvest was made earlier in June of 1974 by Carl Rice of BLM. At this time the burs were dry and dropping from the shrubs. The 1973 and 1974 collections had initial germinations of 8%. After 18 months of storage of the 1973 collection, there was no significant difference in germination (average 7%) between burs from various storage conditions (dried to 5.1% moisture and kept sealed at -15 C, 4 C, and room temperature or sacked under warehouse conditions) (Kay 1975B).

Optimal germination temperatures in the 1974 collection were between 15 and 25 C; germinations were 26-18% in this range, with no germination at 2 or 5 C (Kay 1945A). The warmer spring temperatures used by Williams et al. (1974) in depth of planting studies are apparently responsible for higher reported emergence than the fall test (Kay 1975A). Optimum planting depth was 1 cm, with little or no emergence from 2 cm.

In testing the effects of various seed treatments, Graves et al. (1975) found that 7- and 14-day germinations were equally improved by activated carbon or stratification in moist sand at 2 C for 30 days resulting in 24% final germination of seed of 26% fill compared to 17% with untreated seed (Fig. 1). Heat treatment did not raise the germination percentage significantly.

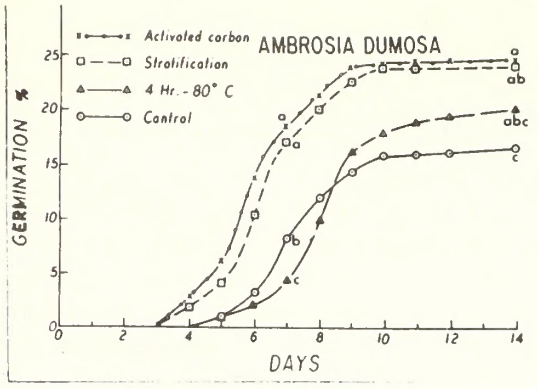


Fig. 1. Germination of burs, representing treatments that showed significant differences from the control. Germination at days indicated by the same letter are not different according to Duncan's NMRT ($P < 0.05$).

Ambrosia is easier to establish by transplanting than spot seeding (Graves 1976). Transplanting nursery-grown seedlings at two Mojave test sites following the coldest winter period (in February resulted in 42 and 54 % establishment.

Success from spot seeding was 0 and 4% at the same sites. A one-time irrigation treatment did not improve results of either transplanting or spot seeding.

References

Chase, V. C. and B. R. Strain. 1966. Propagation of some woody desert perennials by stem cuttings. Madrono 18(8):240-243.

Clark, W. H. and P. L. Comanor. 1973. A quantitative examination of spring foraging of Vermoesser pengandei (Mayr.) in northern Death Valley, California. (Hymenoptera: Formicidae) Am. Midl. Nat. 90(2):467-474.

Coville, F. V., 1893. Botany of the Death Valley expedition. The U.S. Nat'l. Herbarium. Vol. IV. pp. 51 ff.

Geissman, T. A. and S. Matsueda. 1968. Sesquiterpene lactones. Constituents of diploid and polyploid Ambrosia dumosa (Tray. Phytochemistry 7(9):1613-1621.

Graves, W. L., B. L. Kay, and W. A. Williams. 1975. Seed treatment of Mojave Desert shrubs. Agronomy Journal. Vol. 67, pp. 773-777.

_____. 1976. Revegetation of disturbed sites with native shrub species in the Western Mojave Desert. (In test of seeds of Mojave Desert shrubs. Progress report BLM contract 53500-CT4-2(N)) pp. 11-35.

Kay, B. L. 1975A. Test of seeds of Mojave Desert shrubs. Progress report. B.L.M. contract 53500-CT4-2(N).

_____. 1975B. Unpublished data.

Lunt, O. R., J. Letey, and S. B. Clark. 1973. Oxygen requirements for root growth in three species of desert shrubs. Ecology 54(6):1356-1362.

McMinn, H. E. 1951. An illustrated manual of California shrubs. Univ. of California Press, Berkeley, Calif. p. 601.

Muller, C. H. 1953. The association of desert annuals with shrubs, Amer. J. Bot. 40(2):53-60.

Munz, P. A. and D. D. Keck. 1959. A California flora. Univ. of California Press, Berkeley, Calif. p. 1104.

Payne, W. W., P. H. Raven, and D. W. Kyhos. 1964. Chromosome numbers in compositae. IV. Ambrosieae. Amer. J. Bot. 51(4):419424.

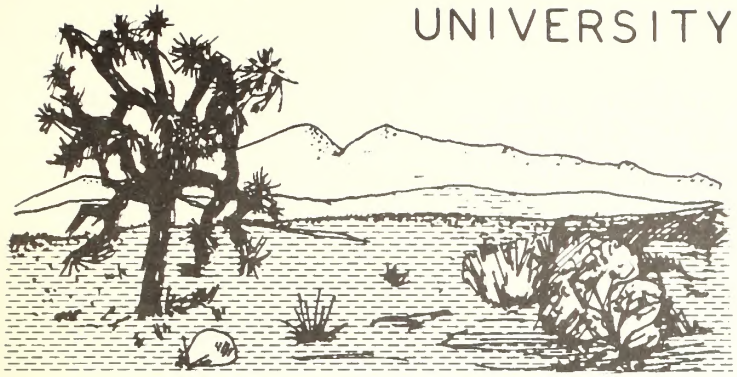
Stark, N. 1966. Review of highway planting information appropriate to Nevada. Desert Research Institute, Univ. of Nevada. College of Agric. Bulletin No. B-7. p. 76.

Wallace, A., E. F. Frolich, and G. V. Alexander. 1973. Effect of steam sterilization of soil on 40 desert plant species. Plant Soil 39(2): 453-456.

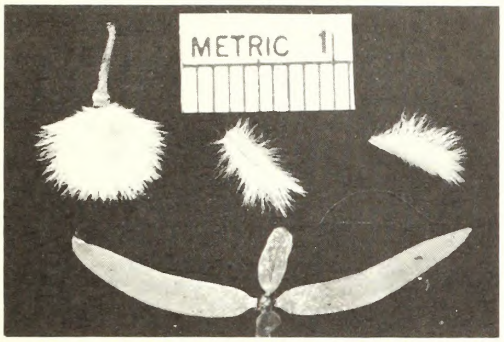
_____., E. M. Romney, and R. T. Mueller. 1969. Effect of the phosphorus level on the micronutrient content of Franseria dumosa. Phyton Int. J. Exp. Bot. 26(2):151-154.

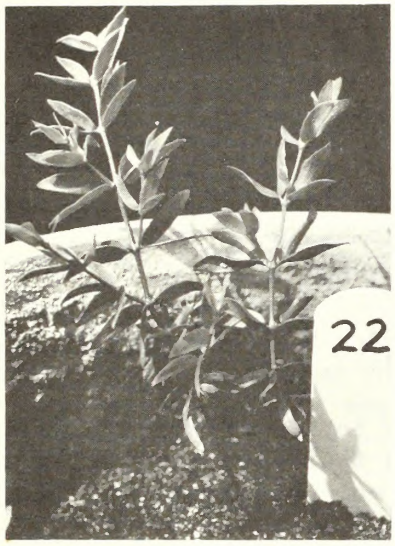
Weiland, P. A. T., E. F. Frolich, and A. Wallace. 1971. Vegetative propagation of woody shrub species from the northern Mojave and southern Great Basin deserts. Madrono 21(3):149-152.

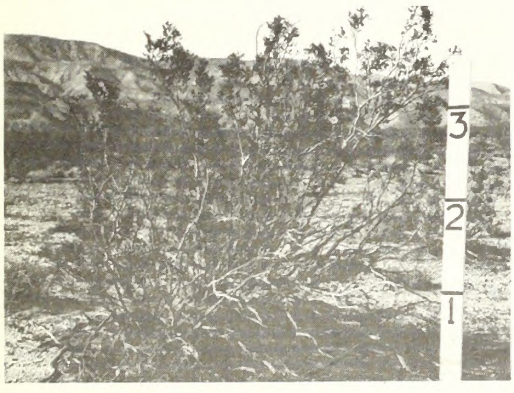
Williams, W. A., O. D. Cook, and B. L. Kay. 1974. Germination of native desert shrubs. Calif. Agric. Aug., p. 13.



Mojave Revegetation Notes







Larrea tridentata Sessé & Mociño

[Sometimes incorrectly referred to as Larrea divaricata, a South American species].

Creosote bush

Family: Zygophyllaceae

Habit: Erect, diffusely branching evergreen shrub; branches 1-3 (-4) m long; strongly scented, resinous; heavy root crown, main stems arising from the base at an angle; branches slender, brittle, simple or somewhat branched, with dark, glutinous or corky nodal rings.

Leaves: Opposite, bipinnate leaflets: stalkless, lanceolate or oblong, indistinctly 3-veined from the base, finely varnished to silky hairy or smooth, about 6-10 mm long, 3-4 mm broad.

Flowers: Yellow, regular, solitary; located on short side-branchlets. 5 petals, 6-10 mm long, turned sidewise like propeller blades; stamens each with a scale attached to the filament, the scale irregularly slashed; flowering after rain, Nov. to May.

Fruit: A globose capsule, usually about 6-10 mm long, separating into 5 carpels containing single-seeded, densely white or rusty-hairy nutlets.

Top to botton: seed capsule with individual carpels and emerging seedling with cotyledons and first leaves. Center: seedling and mature shrub.

The most prevalent scent of the North American deserts may be the penetrating odor of the creosote bush, the most common and widely distributed shrub of those regions. Larrea tridentata is dominant over great areas of desert below 5,000 ft elevation from Kern Co., in California, to Utah, Texas, and Mexico, in plant communities aptly described as Creosote Bush Scrub (Munz, et al., 1959).

Standley (1920) described various uses of the creosote bush: "Flower buds, pickled in vinegar, are said to be eaten like capers. The plant is much used in domestic medicine, especially for rheumatism, a decoction of the leaves being employed for baths or formentations. The decoction is said, also, to have remarkable antiseptic properties, and is said to be applied to bruises and sores. It is taken internally for gastric disturbances and venereal disease. A reddish-brown lac is often deposited on the branches by a small scale insect. This lac is used in many parts of Mexico for dyeing leather red, and the Coahuilla Indians of California employ it as a cement. The same Indians use a decoction of the plant for interstitial complaints and for tuberculosis. The Pima Indians of Arizona drink a decoction of the leaves as an emetic, and apply the boiled leaves as poultices to wounds and sores."

Colton (1943A,1943B) investigated the economic posisiblities of the lac insect on Larrea, and concluded that, although artificial cultivation seemed possible, the resin produced would be of little use as varnish (though having possibilities in making phonograph records) and the cost of collection economically prohibitive.

Nordihydroguaiaretic acid (NDGA), a white crystalline solid prepared from Larrea, has been used as an antioxidant in food but was discontinued following investigations of its safety (Grice et al., 1968; Cranston et al., 1947). Waller et al. (1945) showed that NDGA has powerful germicidal properties, as indicated by use of the plant by native peoples. Tsuchiya et al. (1944) demonstrated the antibiotic activity of the substance against certain bacteria in vivo. NDGA content may reach 10% in the leaves of the creosote bush, although California specimens average 4% NDGA at 4,000 ft elevation, and 6% at 1,500 ft (Grisvold, 1948).

The shrub was an important fuel source for Indians (Munz et al., 1959) and desert travelers. Coville (1893) noted that dead branches of the creosote bush were the major fuel source throughout much of the Death Valley expedition.

The palatability of the shrub is extremely low for all grazing animals (Sampson, et al., 1963) and it has been reported as poisonous to livestock (Pammel, 1911), though an edible livestock feed has been commercially produced (Duisberg, 1952). The creosote gall midge (Asphondylia) produces marble-sized leafy galls on the stems, but only a few insects are known to feed on Larrea (Benson et al., 1954, Comstock, 1939; Comstock et al., 1940) The blacktailed jackrabbit (Lepus californica deserticola) actively trims lower twigs from the shrub , leaving them lying where they fall, and the woodrat (Neotoma) is responsible for some higher trimming, building up collections of stones, sticks, and creosote bush twig ends around its burrows (Jaeger, 1948). The most important herbivore is the kangaroo rat (Dipodomys meriami Mearns), which shows a high preference for creosotebush seeds and may be important to seed dispersal through storing seed in small, subsurface caches (Reynolds, 1950).

Though usually excluded from markedly saline soils (Benson et al., 1954; Wallace et al., 1973), Larrea is adapated to many of the Southwestern soil types. "Larrea was not dominant where pH of the topsoil was 8.4 or above, or 173 ppm sodium or above" (Barbour 1969). The creosote bush is best suited to the well drained porous soils of sandy or gravelly mesas and gentle slopes; on such sites pure stands are not uncommon (Benson et al., 1954; Went et al., 1949; Yang, 1950). A high soil-oxygen requirement accounts for the shrub's exclusion from poorly drained, fine-textured soils (Livingston, 1910; Lunt et al., 1973). "Caliche" hardpans are often present in Larrea-dominated areas (Gardner, 1951; Nichol, 1952; Shreve et al., 1933). The extensive shallow root systems of Larrea allow it to occupy these calicheunderlain sites by absorbing any light rainfall which occurs (Cunningham et al., 1973; Cannon, 1911).

Beatley (1974) investigated the effects of rainfall on Larrea in Nevada. The shrub was found on sites with recorded rainfall as low as 120 mm (4.72 in.) and was absent where rainfall exceeded 183 mm (7.20 in.). Reproductive success, as shown by 20-60% seed germinability, was correlated with rainfall of 80-150 mm (3-6 in) during the seed production season. Shrubs growing in areas of high rainfall, or along water courses, developed diseased flowers. High rainfall in the period Jan-Sept. was not detrimental to established plants, although fruit production decreased.

Optimum germination conditions have been determined by Barbour (1968) to be darkness, 23 C, leaching the mericarps with running water, wetting and drying cycles, exposure to cold temperatures prior to sowing, and maintenance of the planting medium at near-zero osmotic pressure low in NaCl. Went, et al. (1949) correlated rainfall and temperature immediately following the rain with Larrea germination. If the temperature exceeded 30 C or fell below 10 C, there was no germination. Tests of hulled or unhulled seed of Larrea tridentata, subjected to various pre-planting treatments by Graves et al. (1975) suggest that planting hulled seed treated with thiourea may improve germination (Figure 1.). The success of a 15-hr soaking treatment or mixing the seed with moistened 12 x 50 caliber activated carbon indicates that an inhibitor in the hull may limit germination. In contrast, Barbour (1968) found presence or absence of the mericarp about the seed had no effect on germination. Knipe and Herbel (1966) observed that extracts from Larrea divaricata carpels did not affect the total germination of seeds removed from the carpels although such seeds germinated faster.

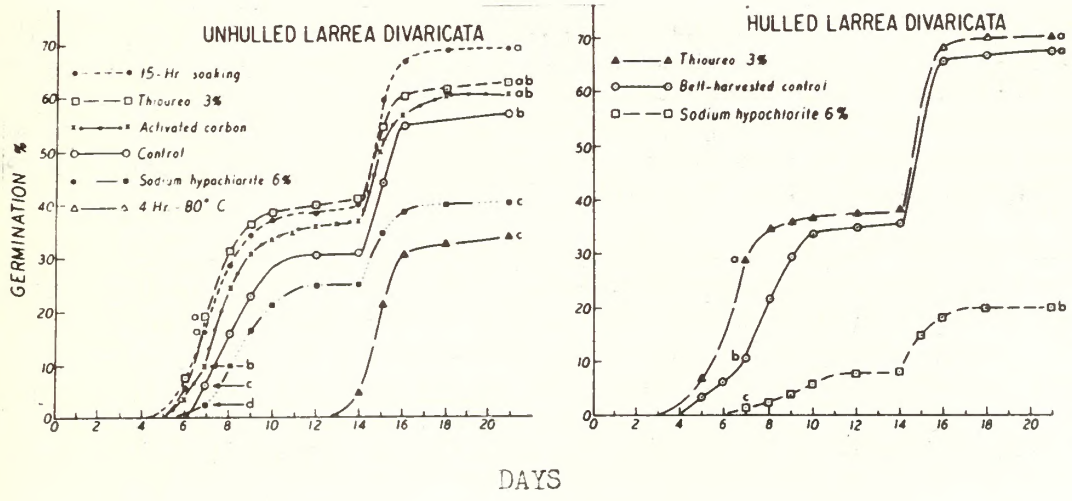


Fig. 1. Germination of seeds representing treatments that showed significant differences from the control (Graves et al. 1975). Temperatures were increased from 21C to 26C on the 14th day. Germinations at days indicated by the same letter are not different according to Duncan's NMRT ($P < 0.05$).

Seed collected in the Mojave Desert in August, 1973, had a purity of 56%. The cottony nature of the seeds prevented cleaning. Pure carpel weight was 180,000/kg (81,800/lb) with a fill of 56%, and initial germination was 17% (Kay, 1975A). Though the carpels do remain on the plant after maturity, they eventually fall to the ground and are easily windblown. Carpels collected from the ground had only half the germination of the bush collection (Kay, 1975A). After 18 months of storage in various conditions (dried to 3.7% moisture, and kept sealed at -15C, 4C, and room temperature, and sacked in warehouse conditions) germination decreased from the initial 17% to 2-4% for all treatments (Kay, 1975B). Average germination was 74% at 17C during an eight-year study in New Mexico (Valentine et al. 1968).

The hull or mericarp may be removed from the seed by hammermilling at 1750 rpm on a 1/4-inch diameter screen and separating on a 2-screen clipper cleaner using a top No. 6 round screen and a No. 25 base screen. A belt harvester, used to shell alfalfa, was also used successfully by Graves et al. (1974). Hammermilling yielded 87.5% compared to 67% from the belt harvester. However, seed damage and abnormal seedlings were greater from hammermilled seed. Hand-hulled seed had the best germination (Figure 2).

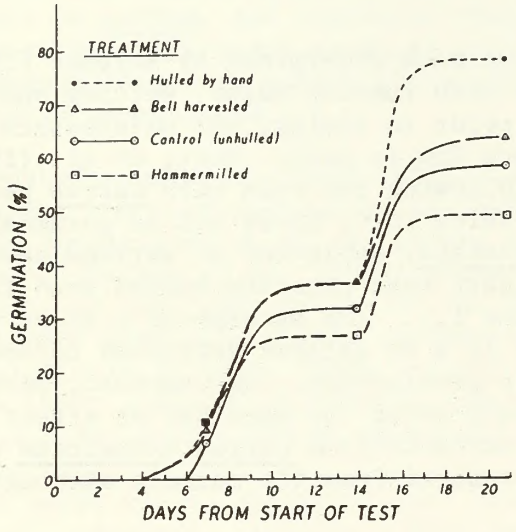


Figure 2. Effect of method of mericarp removal on seed germination of Larrea tridentata.

Went et al. (1949) reported that germination after rain in Death Valley occurred only where seed was covered with 1 cm of loose sand. In emergence testing, Williams et al. (1974) recorded highest percentages (viable seed basis) for the 1-cm depth of planting, 82% in 9.0 days, and a 60% emergence (over 10.5 days) from a 2-cm depth. Kay (1975A) showed that Larrea did not emerge from any depth during the winter.

Cannon (1918) found 32C to be optimum for root growth, and 15C to be the lower limit for root growth efficiency. Barbour (1968) obtained maximum root growth at 29C in a slghtly acidic medium low in NaCl and near-zero in osmotic pressure. Water condensed on rocks from distillation in the soil and available soil water are major sources of water for Larrea, and soil temperature governs delivery rate of distilled water. A temperature range of 10C with a 0-3 cm soil at a maximum of 36-40C is essential for significant distillation (Stark, et al. 1969).

Went et al. (1968) found that fungi have an important biological and mechanical role in desert soils. Sheps (1973) tied seedling survival to the presence of soil fungi in the desert litter. Desert litter, when added to field plots, aided in artificial establishment of Larrea; live seedlings dug up in the field had abundant mycelium, whereas dead ones had little or none. Valentine et al. (1968) studied Larrea establishment on rangeland in New Mexico. Pioneer plants lagged in attaining seed-producing size because of extensive rabbit clipping and trampling by livestock, resulting in very slow invasion of new territory at distances from seedbearing plants. Natural establishment along the fringes of a seed-bearing population can be quite rapid, although, as reported by Chew et al. (1965), the shrub has a relatively short seed dispersal distance. "Significant non-central tendencies in age distribution of most stands indicated that germination and survival are rare events, contributing to one-age or several-age stands" (Barbour 1969).

Control of invading creosote bush is best accomplished along the margins of established populations. Phenoxy herbicides are not useful for killing this plant, although picloram is most effective, especially when applied in fall to kill regrowth following mowing (Valentine, 1970).

References

Adams, S., B. R. Strain, and M. S. Adams. 1970. Water repellant soils, fire, and annual plant cover in a desert scrub community in southeastern California. Ecology 51:676-700.

Barbour, M. G. 1968. Germination requirements of the desert shrub Larrea divaricata. Ecology 50:679-685.

_____. 1969. Age and space distribution of the desert shrub Larrea divaricata. Ecology 50:679-685.

Beatley, J. C. 1974. Effects of rainfall and temperature on the distribution and behavior of Larrea tridentata (creosote bush) in the Mojave Desert of Nevada. Ecology 55(2):245-261.

Benson, L. and R. A. Darrow. 1954. The trees and shrubs of the southwestern deserts. Second edition. Univ. of New Mexico Press, Albuquerque. pp. 218.

Cannon, W. A. 1911. The root habits of desert plants. Carnegie Inst. Wash. Publ. 131. pp. 1-96.

_____. 1918. Evaluation of the soil temperature factor in root growth. Plant World 21:64-67.

Chew, R. M. and A. E. Chew. 1965. The primary productivity of a desert shrub (Larrea tridentata) community. Ecol. Monogr. 35:355-375.

Colton, H. S. 1943A. What can we do about lac? Plateau 15(3):46-48.

_____. 1943B. Life history and economic possibilities of the American lac insect, Tachardiella larrea. Plateau 16(2):21-32.

Comstock, J. A. 1939. A new Sparganothis with notes on early stages (Lepidoptera, Torgicidae). Bull. So. Calif. Acad. Sci. 38(2):120-121.

_____ and M. Dammers. 1940. Notes on the life history of Sparganothis larreana Comst. Bull. So. Calif. Acad. Sci. 38(3):199-200.

Cook, C. W. 1971. Recovery of desert plants in various states of vigor. J. Range Management 24(5):339-343.

Coville, F. V. 1893. Botany of Death Valley expedition. The U.S. Nat'l. Herbarium. Vol. IV. pp. 51 ff.

Cranston, E. M., M. J. Jensen, A. Moreu, T. Brey, E. T. Bell, and R. N. Bieter. 1947. The acute and chronic toxicity of nordihydroguaiaretic acid. Fedn. Proc. Fedn. Am. Soc. Exp. Biol. 6:318.

Cunningham, G. L. and J. H. Burk. 1973. The effect of carbonate deposition layers ("caliche") on the water status of Larrea divaricata. Am. Midl. Nat. 90(2):474-480.

Duisberg, P. C. 1952. Development of a feed from creosote bush (Larrea divaricata) determination of its nutritive value. J. Animal Sci. 11:174-180.

Gardner, J. L. 1951. Vegetation of the creosote bush area of the Rio Grande Valley in New Mexico. Ecol. Monog. 21:379-403.

Graves, W. L., B. L. Kay, and W. A. Williams. 1974. Seed-treatment studies of seven Mojave Desert shrub species. pp. 7-33. In Kay, B. L. Test of Seeds of Mojave Desert Shrubs. Progress report, BLM Contract No. 535-CT4-2(N).

_____, _____, and _____. 1975. Seed treatment of Mojave Desert Shrubs. Agronomy J. 67:773-777.

Grice, H. C., G. Becking, and T. Goodman. 1968. Toxic properties of nordihydroguqiaretic acid [Larrea divaricata]. Food Cosmet. Toxicol. 6(2):155-161.

Grisvold, O. 1948. A preliminary survey of the occurrence of nordihydroguaiaretic acid in Larrea divaricata. J. Am. Pharm. Assoc. Sci. Ed. 37(5):194-196.

Jaeger, E. C. 1948. Who trims the creosote bushes? J. Mammalogy. 29(2): 187-188.

Kay, B. L. 1975A. Test of seeds of Mojave Desert shrubs. Progress report. B.L.M. Contract No. 53500-CT4-2(N).

_____. 1975B. Unpublished data.

Livingston, B. E. 1910. Relation of soil moisture to desert vegetation. Bot. Gaz. 50:241-256.

Martin, S. C. 1974. Larrea tridentata Vail. Creosote bush. In: Seeds of Woody Plants in the United States. Agriculture Handbook No. 450. Forest Service, USDA. pp 486-487.

McMinn, H. E. 1951. An illustrated manual of Califoria shrubs. Univ. of California Press, Berkeley, Calif. pp. 257.

Munz, P. A. and D. D. Keck. 1959. A California flora. Univ. of California Press, Berkeley, Calif. pp. 178.

Nichol, A. A. 1952. The natural vegetation of Arizona. Univ. Arizona, Agric. Expt. Sta., Tech. Bulletin 127, 41 p.

Pammel, L. H. 1911. A manual of poisonous plants, chiefly in eastern North America, with brief notes on economic and medicinal plants. The Torch Press, Cedar Rapids, Iowa. 977 p.

Reynolds, H. G. 1950. Relation of kangaroo rats to range vegetation in southern Arizona. Ecology 31:456-473.

Sampson, A. W. and B. S. Jesperson. 1963. California range brushlands and browse plants. Univ. of California, Div. of Agric. Sci. Calif. Agric. Expt. Sta. Extension Service Manual 33. 96 pp.

Sheps, L. O. 1973. Survival of Larrea tridentata seedlings in Death Valley National Monument, California. Isr. J. Bot. 22(1):8-17.

Shreve, F., and T. D. Mallery. 1933. The relation of caliche to desert plants. Soil Sci. 35(2):99-112.

Standley, P. C. 1920. Trees and shrubs of Mexico. U.S. Nat'l. Herbarium 23, part 3. pp. 517.

Stark, N. and L. D. Love. 1969. Water relations of three warm desert species. Isr. J. Bot. 18(4):175-190.

Tsuchiya H. M., C. H. Drake, H. P. Halvorson, and R. N. Bieter. 1944. An antibacterial substance from a plant. J. Bact. 47:422.

Valentine, K. A. 1970. Creosote bush control with phenoxy herbicides, picloram, and fuel oil in southern New Mexico. N. Mex. Agr. Expt. Sta. Bull. 544. pp. 3-12.

_____ and J. B. Gerard. 1968. Life-history characteristics of the Creosote bush, Larrea tridentata. N. Mex. Agr. Exp. Sta. Bull. 526. 32 pp.

Wallace, A., E. M. Romney, and V. Q. Hale. 1973. Sodium relations of desert plants: I. Cation contents of some plant species from the Mojave and Great Basin deserts. Soil Sci. 115(4):284-287.

Waller, C. W., and O. Grisvold. 1945. A phytochemical investigation of Larrea divaricata Cav. J. Am. Pharm. Assoc. Sci. Ed. 34(3):78-81.

_____, and N. Stark. 1968. The biological and mechanical role of soil fungi. Proc. Nat. Acad. Sci. 60:497-504.

Went, F. W. and M. Westergaard. 1949. Ecology of desert plants. III. Development of plants in Death Valley National Monument, California. Ecology 30:26-38.

Williams, W. A., O. D. Cook, and B. L. Kay. 1974. Germination of native desert shrubs. Calif. Agric., Aug. pp. 13.

Yang, T. W. 1950. Distribution of Larrea tridentata in the Tucson area as determined by certain physical and chemical factors of the habitat. M.S. Thesis, Univ. of Arizona. 47 p.

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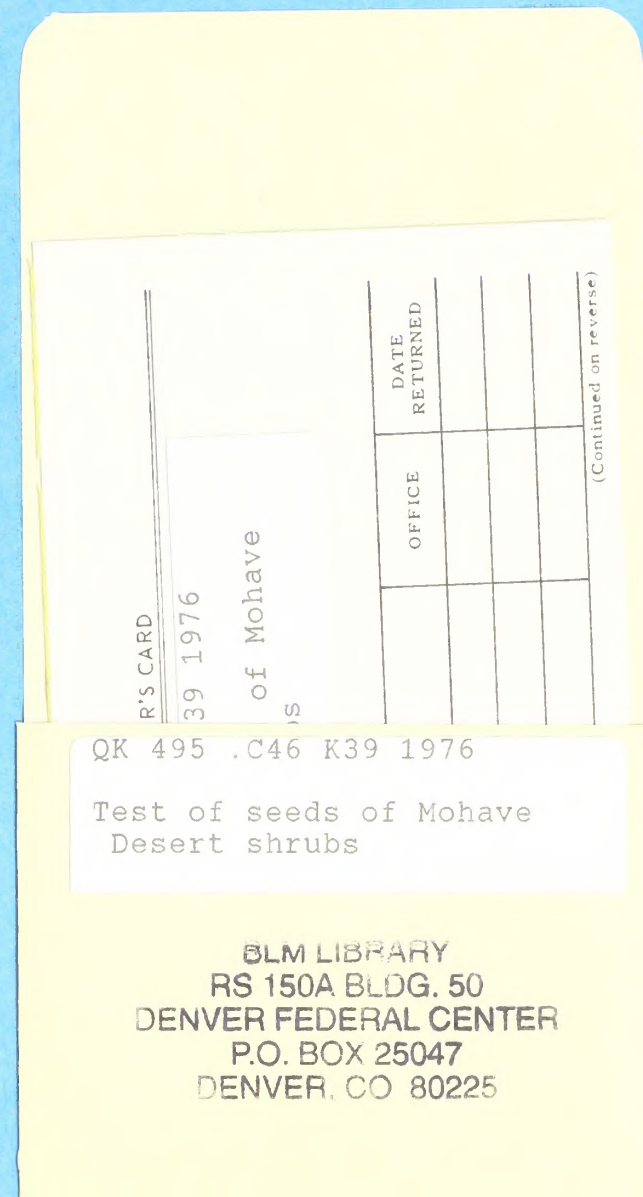

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